TM 1-412

WAR DEPARTMENT

U. S. Dept. of Army

TECHNICAL MANUAL

AIRCRAFT PROPELLERS

5 January 1944

TECHNICAL MANUAL

MISCELLANEOUS AIRCRAFT EQUIPMENT

CHANGES No. 1 — WAR DEPARTMENT, WASHINGTON 25, D. C., 13 September 1944.

TM 1-412, 5 January 1944, is changed as follows:

APPENDIX (Added)

RECOMMENDED SAFE PRACTICES

The proper method of lifting propellers is as follows:

1. Manually.—When propellers are lifted manually, bend the knees; keep shoulders back; lift with leg muscles. Take a deep breath and hold it until the propeller is up in a comfortable position. Be sure of firm footing. If propeller is too heavy, get help or use a hoist.

2. Hoisting.—Make sure propeller is properly secured. Move the load slowly. Never stand under the propeller in hoisted position; keep others from walking under the load. Do not sling or hoist the load over heads of fellow workers.

3. Cleaning fluids.—Only approved cleaning solvents shall be used in cleaning parts. (See TO 01-1-1, 15 Nov. 43.)

4. Rotating propeller.—Before rotating blades of the propeller when it is in horizontal position on the assembly plate, caution others to stand clear of blades. This also applies when balancing propeller on balancing stand.

5. Balancing pit.—When not in use, the balancing pit shall be kept covered with suitable cover.

6. Storage.—Locally manufactured wooden propeller storage racks shall be designated by a qualified structural engineer. The strength and stresses should be determined before manufacture and adequate factor of safety allowed. Racks should not be painted, but should be coated with clear protective materials, that is, clear varnish or clear shellac. This should be done in order that cracks, splits, and other defects may be detected after the rack has been put in use.

7. Alertness.—Individuals engaged in the maintenance of propellers in the shops, hangars, or on the line shall exercise caution at all times not to create conditions hazardous either to themselves or to their fellow workers.

8. Personal protective equipment.—Safety shoes shall be worn by personnel engaged in the maintenance of aircraft propellers.

[A. G. 300.7 (24 Jul 44).]

AGO 306C 598803°—44

BY ORDER OF THE SECRETARY OF WAR:

G. C. MARSHALL,
Chief of Staff.

OFFICIAL:
J. A. ULIO,
Major General,
The Adjutant General.

DISTRIBUTION:

As prescribed in paragraph 9a FM 21-6; Bn & H 1 (6); Bn 9 (2); IBn 1 (10); IC 9 (3).

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IC 9: T/O & E 9-417.

For explanation of symbols see FM 21-6.

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TECHNICAL MANUAL No. 1-412

WAR DEPARTMENT
WASHINGTON 25, D. C., 5 January 1944

AIRCRAFT PROPELLERS

* This manual supersedes TM 1-412, 21 October 1940, including Changes No. 1, 20 August 1941.

605413°—44——1

SECTION I

GENERAL

1. **Propeller fundamentals.**—*a. General.*—The aircraft propeller usually consists of two or more blades, and a central hub by means of which the blades are attached to a shaft which is driven by the engine. Each blade of an aircraft propeller is essentially a rotating wing. As a consequence of their particular construction, the propeller blades produce air forces, part of which are in a direction to produce *thrust* (fig. 1) to pull or push the airplane through the air and part of which serve to load the engine and thus control its speed.

b. Power source.—The power needed to rotate the propeller blades is furnished by the engine. The propeller is attached directly to the crankshaft of low-horsepower engines; but on high-horsepower engines, it is attached to a propeller shaft which is geared to the engine crankshaft. In either case, the engine rotates the blade airfoils through the air at high speeds and the propeller transforms the rotary power of the engine into thrust power or forward flight.

c. Sections.—For analytical purposes each blade is divided into sections of convenient length. During flight, each section of the blade has a motion which is a combination of the forward motion of the airplane and the circular motion of the propeller. Therefore the resulting path of any section is a screwlike or spiral path (fig. 2). In one turn of the blade all sections move *forward* the same distance but the sections toward the tip move a greater *circular* distance than do the sections toward the hub. Since this is so it is necessary that the pitch angles of sections toward the tip be less than the pitch angles of sections toward the hub. Therefore there is a certain amount of "twist" along the blade.

d. Terms.—Some of the principal propeller terms used throughout this manual are defined as follows:

(1) *Blade (or thrust) face.*—The side of a propeller blade,

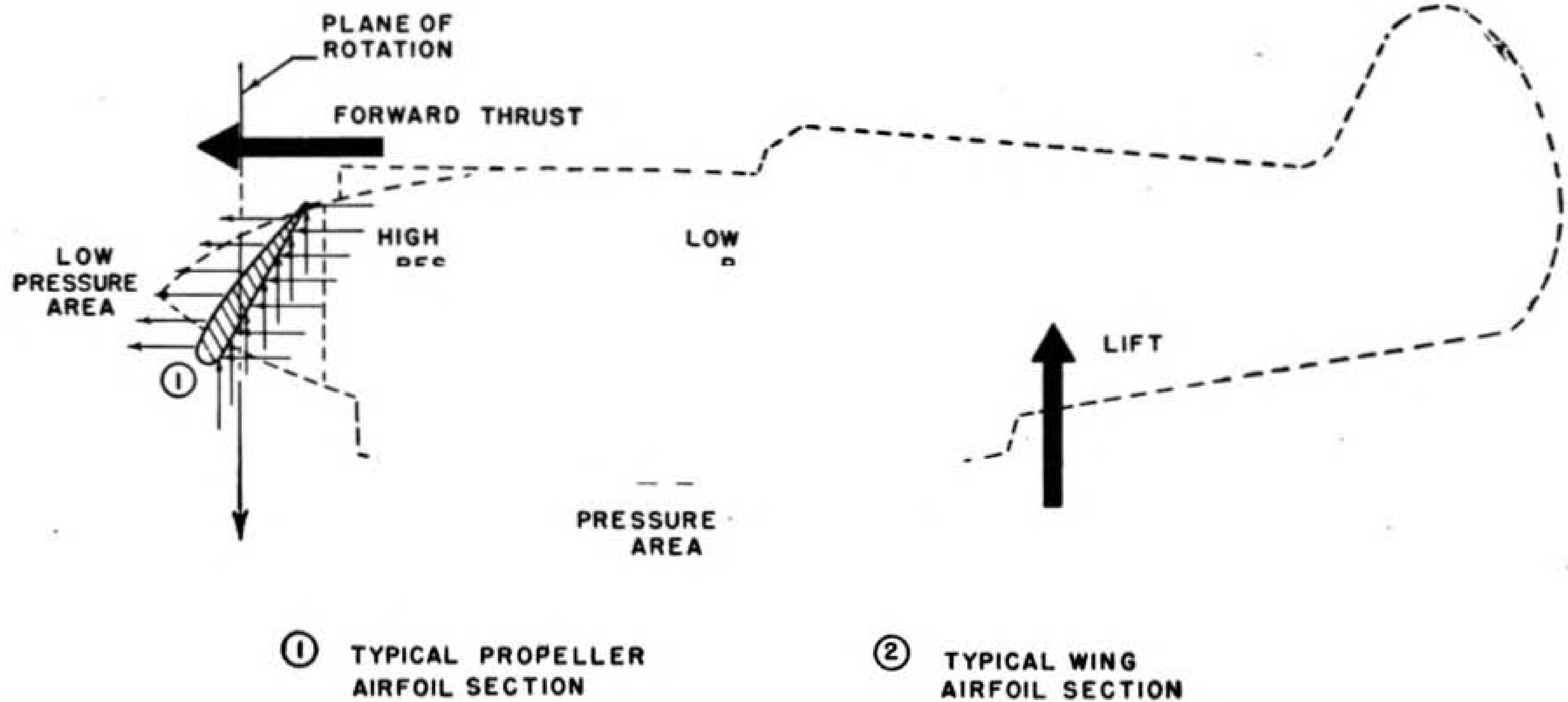


FIGURE 1.—Reactions of airfoils moving through air.

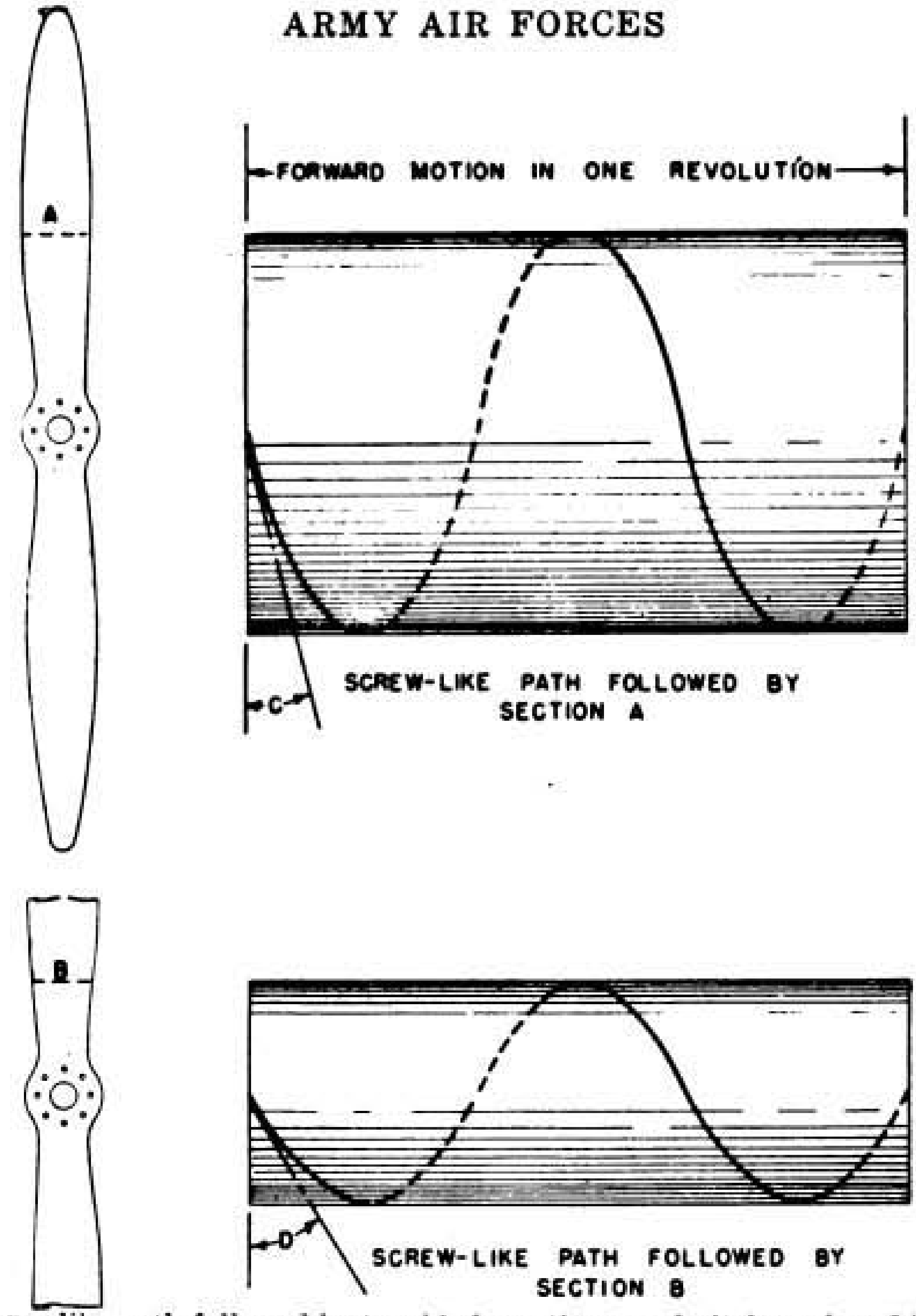


FIGURE 2.—Screwlike path followed by two blade sections, and pitch angles of these sections.

which is usually flat or nearly so, similar to the lower surface of a wing airfoil section (fig. 3).

(2) *Blade back (or camber face).*—The cambered or curved side of a propeller blade, corresponding to the upper surface of a wing airfoil section (fig. 3).

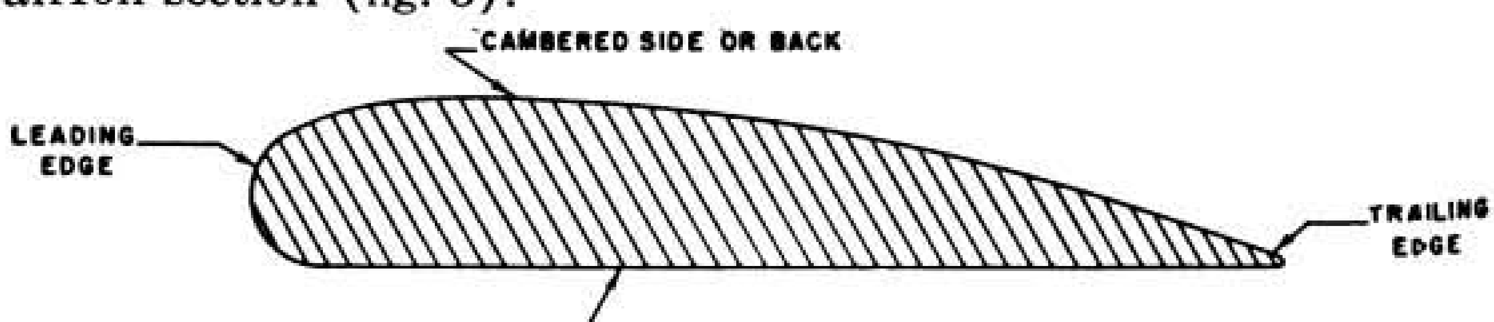


FIGURE 3.—Cross section of blade.

(3) *Leading edge.*—The edge which heads into the air (fig. 3).

(4) *Trailing edge.*—The edge of the propeller blade opposite the leading edge (fig. 3).

(5) *Blade shank.*—The portion of the blade near the blade butt as shown in figure 4. Usually the shank is thick (to give it strength) and cylindrical (to fit the hub barrel). The cylindrical

shank delivers little or no thrust. Some blades are so designed that the airfoil is carried in to the hub. Other blade assemblies use blade cuffs of thin sheets of metal or other material which, when attached to the blade shank, carry the airfoil design to the hub.

(6) *Blade butt or base.*—The end of the blade which fits into the hub (fig. 4).

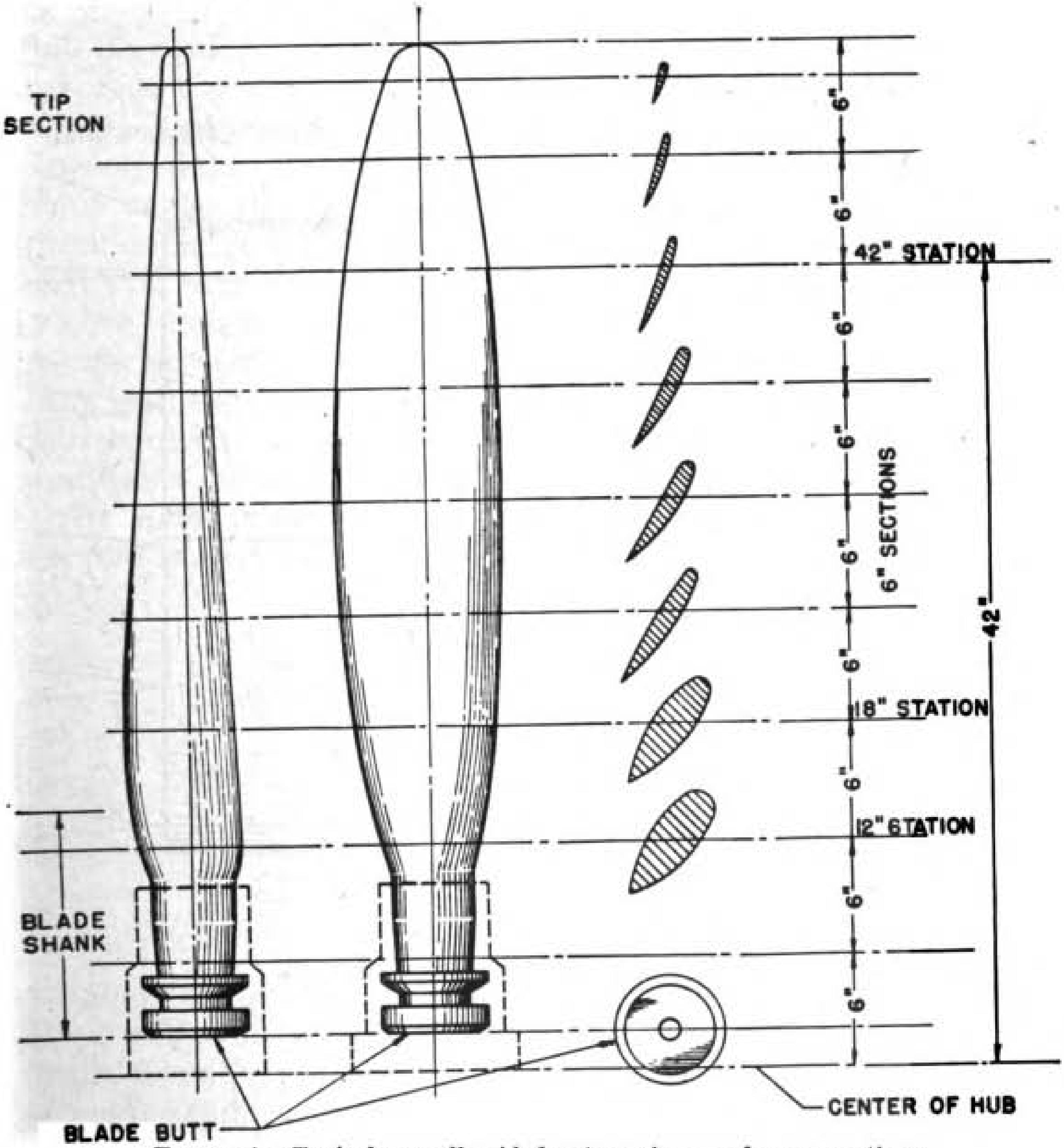


FIGURE 4.—Typical propeller blade: two views and cross sections.

(7) *Blade stations.*—Designated distances on the blade as measured from the center of the hub or from some station-reference line marked near the tip. It is common practice to designate these stations at 6-inch intervals. For example, the 12- to 18-inch blade section is between the 12- and 18-inch stations, as shown in figure 4.

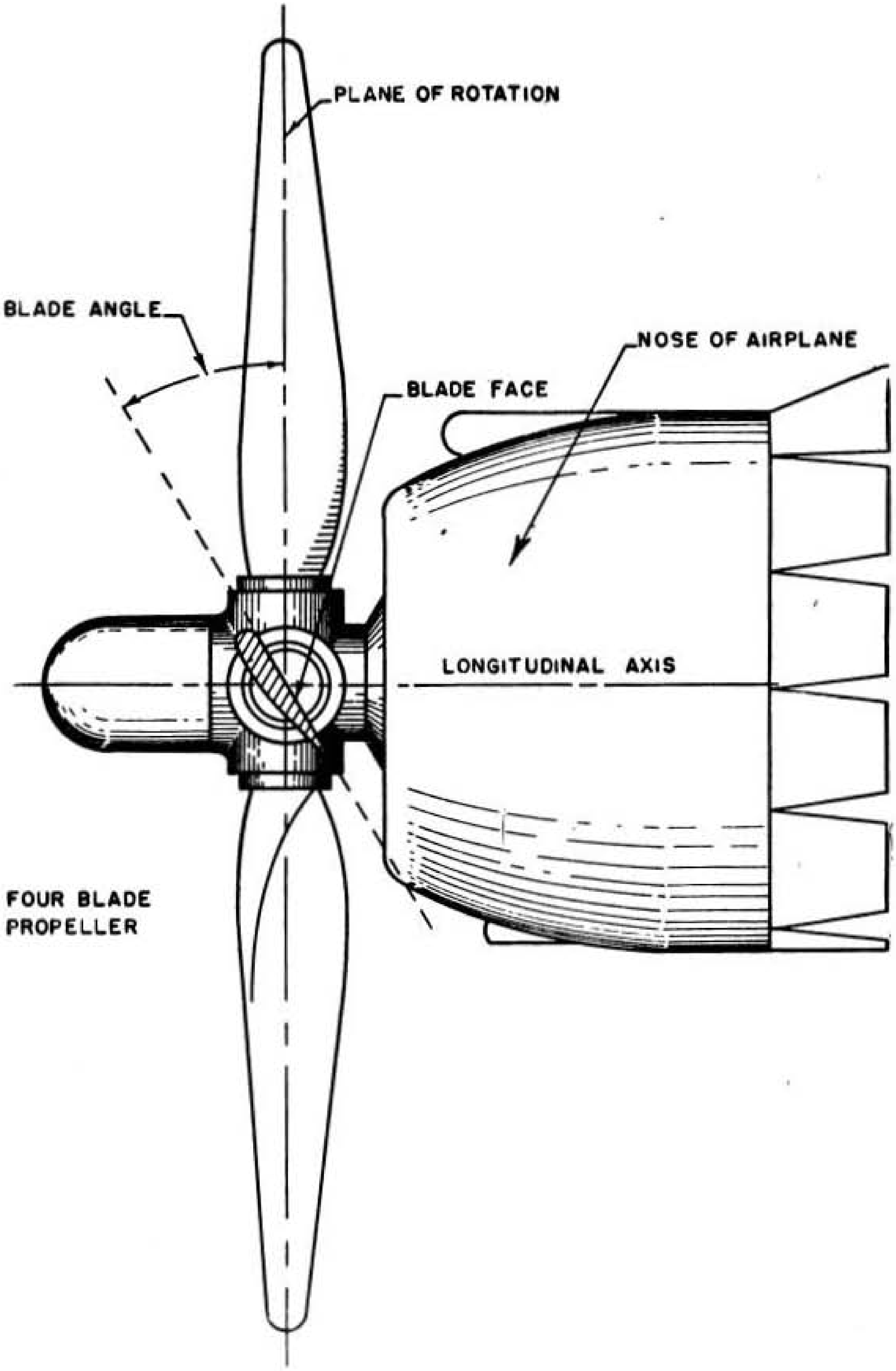


FIGURE 5.—Blade angle.

Blade stations are used as reference lines for locating blade markings, antiglare areas, the proper point for measuring the blade angle, etc.

(8) *Blade angle.*—The angle between the face or chord of a particular blade section and the plane in which the blades rotate (fig. 5). The blade angle of each section of a particular blade will be different from the blade angle of any other section, inasmuch as the blade is a twisted airfoil. However, in setting a blade in its hub the blade angle is measured at one particular station, depending upon the diameter of the propeller. If the blade angle at this station is correct, the blade angle at every other point of the accurately designed and manufactured blade will be correct. The blade angles for different airplane and engine combinations are specified in Technical Orders. It is extremely important that the blades of any propeller be set at the proper angle, since a 1° change in blade angle will affect the engine rpm of a direct-drive engine between 60 to 90 rpm (with geared engines the figure will vary with the gear ratio). However, deviation from these settings as much as 1° above or ½° below may be authorized where local conditions make it desirable.

(9) *Blade track.*—If like points on all blades of a propeller follow the same relative path, the propeller is said to be "in track."

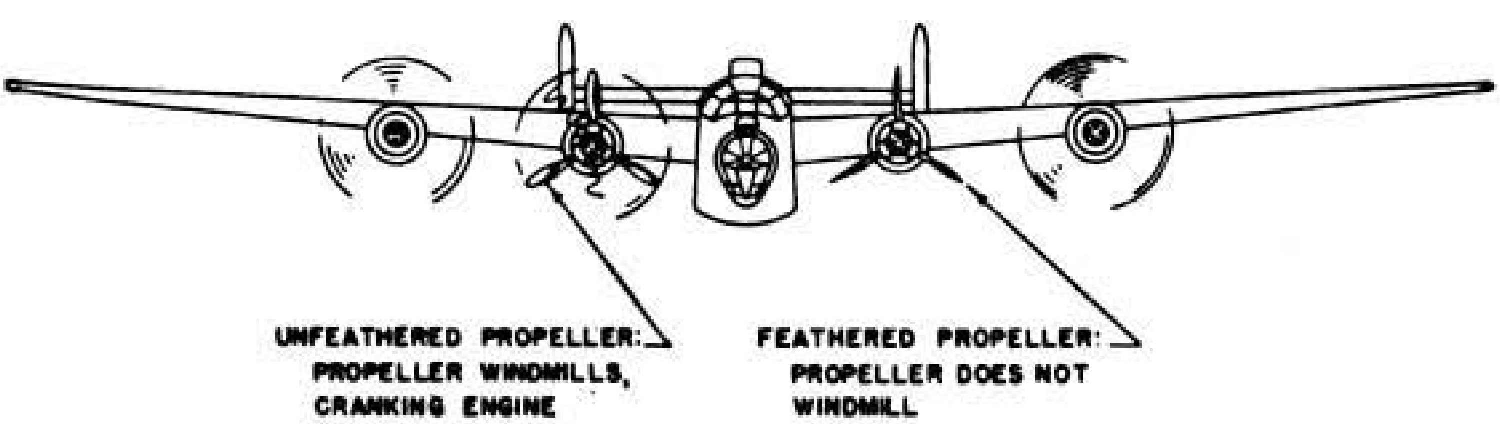


FIGURE 6.—Feathered and unfeathered propeller.

(10) *Feathered blade.*—A "feathered" blade is in an approximate in-line-of-flight position, or is streamlined with the line of flight. Some types of propellers have a feathering feature. In case of engine failure on twin-engine or multiple-engine airplanes, the blades may be placed in a feathered position (fig. 6). In this position the pressure of the air on the face and back of the blade is equal, and the propeller will stop rotating, or "windmilling." The ability to stop an engine from rotating in case of engine failure is, from the safety standpoint, the greatest asset of the feathering feature. At the same time, by not windmilling, the feathered propeller produces the least possible drag on the airplane. Flight tests

with one engine of twin-engine and multi-engine airplanes not operating show a definite improvement in all phases of performance with the remaining engine or engines, when the airplanes are equipped with propellers that can be feathered.

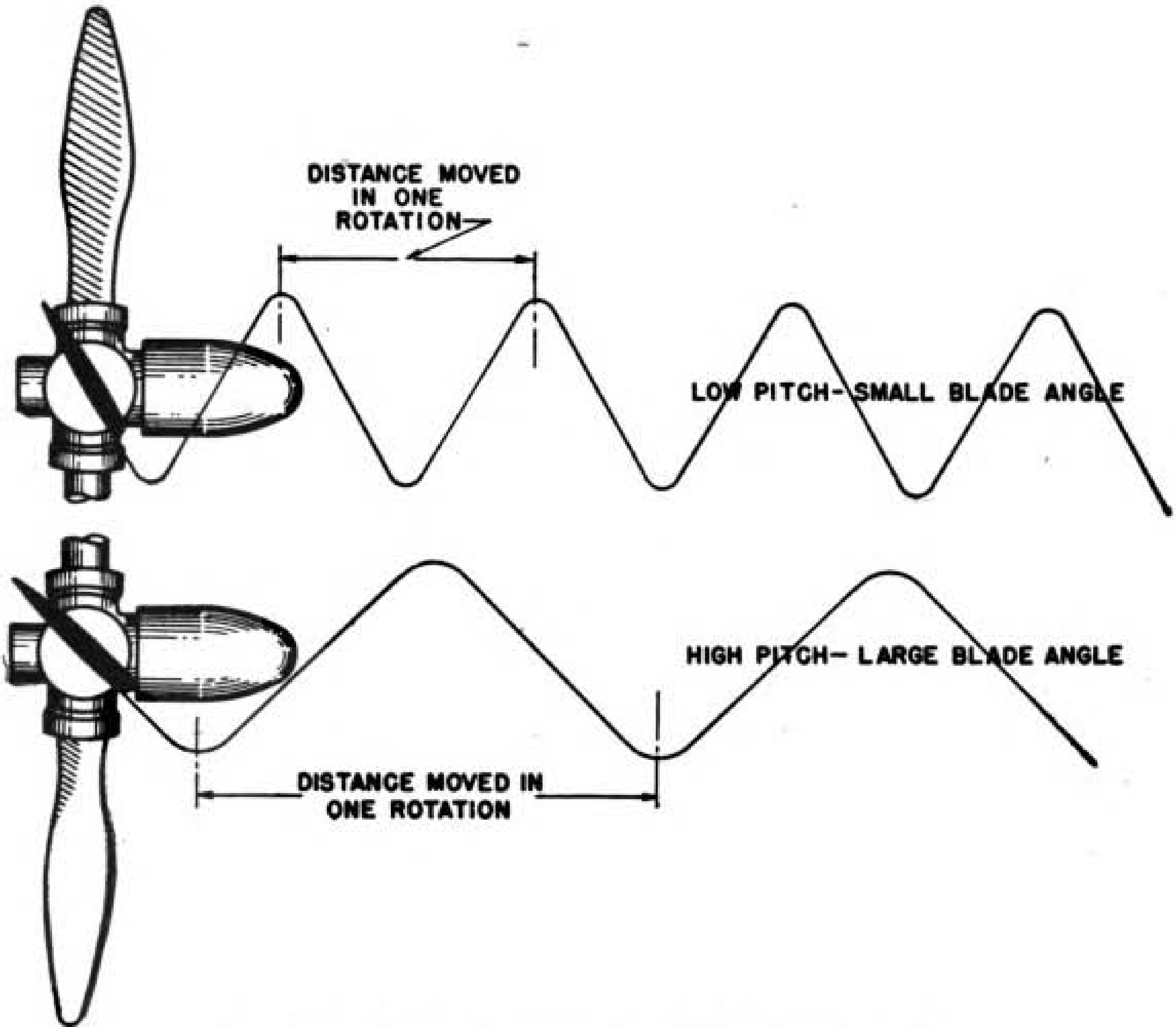


FIGURE 7.—Relation between blade pitch and blade angle.

(11) *Effective pitch.*—The actual distance the airplane moves forward in one revolution of the propeller during flight. The term "pitch" is often used interchangeably with "blade angle," since an increase or decrease in one is usually associated with an increase or decrease in the other (fig. 7).

(12) *Slip.*—The difference between the velocity of the air behind the propeller (caused by the propeller) and that of the aircraft with respect to the undisturbed air well ahead of the propeller. Slip is usually expressed as a percent of this difference in terms of airplane velocity.

2. The propeller airfoil.—*a. The angle of attack* of a propeller blade section is the angle between the face of the blade section and the direction of the relative airstream (fig. 8). Since the rela-

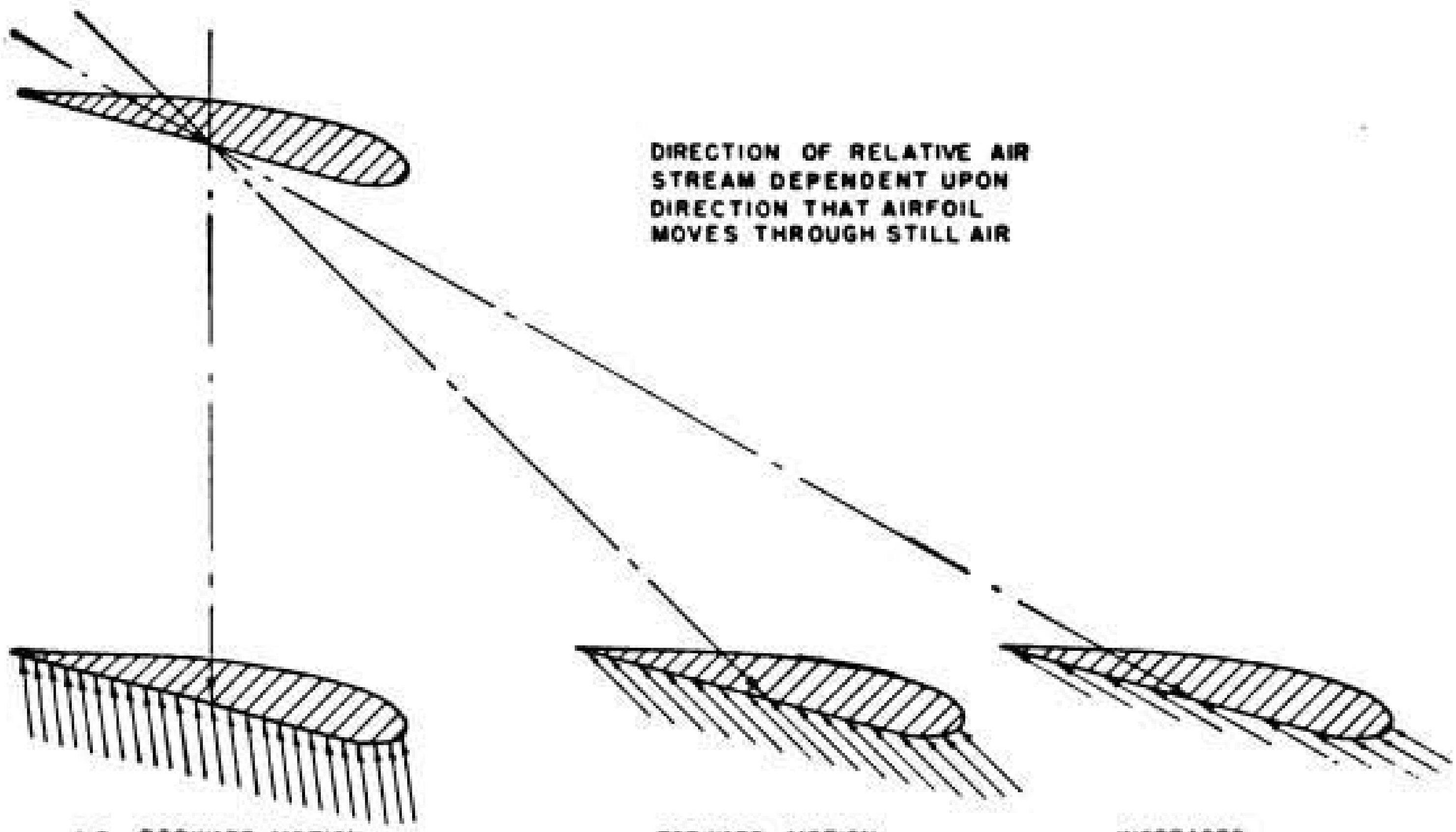


FIGURE 8.—Relative air stream.

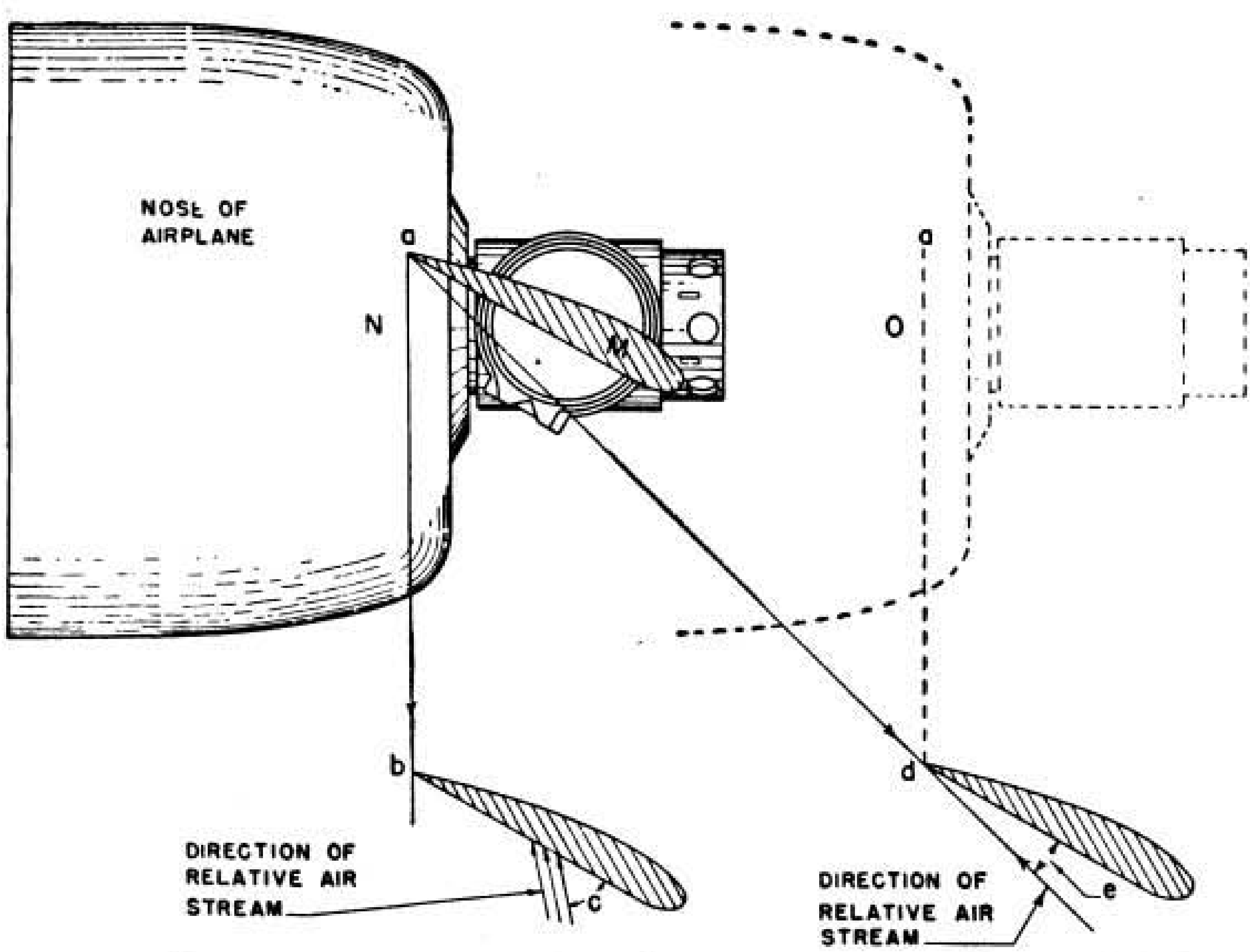


FIGURE 9.—Blade angle and angle of attack; airplane at rest and in normal flight.

tive air motion is along the pitch angle, this angle of attack must be in addition to the pitch angle. The total blade angle is therefore the sum of the two. When the airplane is at rest on the ground, the blade airfoil section *M* of the rotating propeller travels from *a* to *b* (fig. 9); the trailing edge may be said to describe the plane of rotation represented by the line *ab*. Previously, the relative wind was considered as resulting from the forward motion of the airplane and the circular motion of the blade sections. When running the engine on the ground (without forward movement of the airplane) there is still a relative wind, caused by the flow of air through the propeller, and a certain amount of pitch angle of the air motion with respect to the blade sections. Therefore, the angle of attack will be the angle *C*, or the angle at which the section meets the relative airstream. However, in flight the airplane moves forward, and as it moves forward from *N* to *O*, the airfoil section *M* will travel from *a* to *d* and the trailing edge follows the path represented by line *ad* which represents the relative airstream. The angle of attack therefore becomes *e*, a smaller angle.

b. Under normal flight conditions the angle of attack usually varies between 0° and 15°. In a power dive it is possible for the airplane to obtain a speed, due to acceleration by the force of

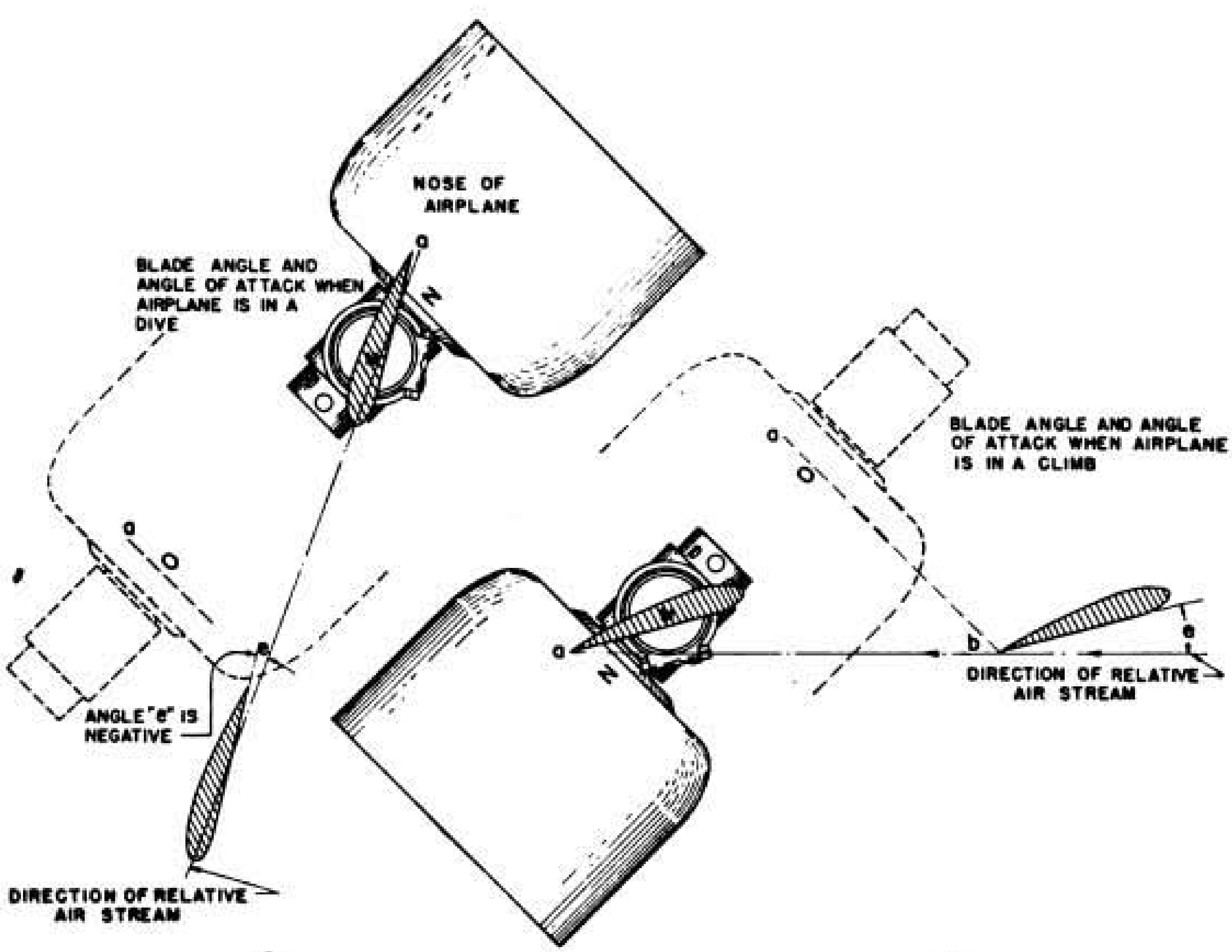


FIGURE 10.—Angle of attack in a dive and in a climb.

gravity, which is greater than the propeller tends to produce. When this occurs the condition shown in figure 10① may be attained. In such a case, the angle of attack *e* is negative and is actually holding the airplane back. In the opposite case, as in a steep climb with the forward speed reduced, the angle of attack becomes greater (fig. 10②). In either case, the aerodynamic efficiency of the propeller is very low. The elimination of this lowering of aerodynamic efficiency is one of the advantages of controllable-pitch propellers.

3. **Types of propellers.**—There are three genéral types of propellers; fixed-pitch, adjustable-pitch and controllable-pitch.

a. The *fixed-pitch* type is manufactured in one piece; no adjustment of the pitch can be made. It is usually a two-blade propeller, and is usually made of wood. Other materials, such as steel, aluminum alloy and phenolic compounds may sometimes be used.

b. The *adjustable-pitch* type usually has a split hub which permits the adjustment of the blades on the ground. The propeller is usually, though not necessarily, removed from the engine when this adjustment is made. Two or more blades may be used. This type of propeller is usually made of steel or aluminum alloy, but wood or other suitable materials may be used.

c. The *controllable-pitch* propeller permits adjustment of the blade angle during operation of the engine in the air or on the ground. Blades may be of steel, aluminum, wood, or suitable resin-bonded materials. The pitch-changing mechanism may be operated mechanically, hydraulically, or electrically.

4. **Advantages and operating principles of controllable-pitch propellers.**—*a. Propeller efficiency.*—Fixed-pitch and ground-adjustable propellers are designed for best efficiency at one rotative and forward speed. In other words, they are designed to fit a set of conditions of both airplane and engine speeds, and any change in these conditions results in lowering the efficiency of both propeller and engine. With controllable-pitch propellers, on which the blade angle may be set or automatically changed to meet a new set of conditions, this lowering of efficiency is greatly reduced. When the airplane goes into a power dive, the blades of a controllable propeller are set or automatically change to a higher angle. As a result the propeller acts less as a brake to the airplane. In the opposite case, that is, when the airplane goes into a steep climb, the blades are set or automatically change to a lower angle. In both cases the propeller aerodynamic efficiency is greatly increased because the propeller blades are permitted to operate at the most advantageous blade angle.

b. Engine efficiency.—(1) The use of controllable-pitch propellers makes it possible to attain the desired engine rpm for particular flight conditions. The use of governors makes it possible to maintain constant engine rpm under a wide range of flight conditions. This is the common practice, particularly for high-horsepower engines. When the airplane goes into a climb, the blade angle of the propeller decreases just enough to keep the engine speed from falling off. The engine can therefore maintain its power output, provided the throttle setting is not changed. When the airplane goes into a dive, the blade angle increases sufficiently to prevent overspeeding, and (with the same throttle setting) the power output remains unchanged. If, instead of changing the speed of the airplane by climbing or diving, the throttle setting is changed, the blade angle will increase or decrease as required to maintain a constant engine speed. The power output (and not rpm) will therefore change in accordance with changes in the throttle setting.

(2) Without any change in blade angle, an unsupercharged engine will lose speed as altitude increases. Under the same conditions, a supercharged engine will gain speed. The governor-controlled constant-speed propeller serves to change the blade angle automatically, keeping the engine speed constant.

(3) To summarize, the change of blade angle necessary to compensate for new conditions of altitude, airplane attitude, and throttle setting for maintaining constant engine rpm is provided by the governor-controlled propeller.

5. Mediums of blade-angle control.—*a.* The pitch-changing mechanisms of controllable propellers used extensively in the Army Air Forces are operated mechanically, hydraulically, or electrically.

(1) Pitch-changing mechanisms that are operated by oil pressure employ some type of piston-and-cylinder arrangement. The piston may move in the cylinder, as is generally the case; or the cylinder may move over a stationary piston. One piston and cylinder mechanism may change the angles of all the blades; or there may be a separate piston and cylinder for each blade. The linear motion of the piston or cylinder is converted by several different types of mechanical linkage into the rotary motion necessary to change the blade angle. The mechanical connection may be through gears, the pitch-changing mechanism turning a drive gear or power gear that meshes with a gear attached to the butt of each blade. Other types of mechanical linkage are also used. The oil pressure for operating these various types of hydraulic

pitch-changing mechanisms in some cases comes directly from the engine lubricating system; in other cases, a separate oil supply is used. When a governor is used with a controllable propeller, engine oil may be used, but the oil pressure is usually boosted by a pump integral with the governor. The higher pressure provides a quicker blade-angle change. Auxiliary oil systems are sometimes used with controllable propellers for the feathering and unfeathering operations when it may be impossible to use the oil supply of a damaged engine.

(2) The electric current for operating electrical pitch-changing mechanisms is supplied by the airplane battery. The electric current drives a small electric motor which turns a series of gears. One of these gears meshes with a gear on the butt of each blade, and the blade angle is thereby changed.

b. The governors used to control the hydraulic and electrical propeller pitch-changing mechanisms are geared to the engine crankshaft and thus are sensitive to changes in rpm. The hydraulic propeller governors direct oil under pressure for operation of the propeller hydraulic pitch-changing mechanisms. The electric propeller governors close and open electrical circuits for operation of the electric motor of the propeller pitch-changing mechanisms. When rpm increases above the value for which a governor is set, the governor causes the propeller pitch-changing mechanism to turn the blades to a higher angle. This angle increase puts a heavier load on the engine, and rpm therefore decreases. When rpm decreases below the value for which a governor is set, the governor causes the pitch-changing mechanism to turn the blades to a lower angle; the load on the engine is lighter, and rpm therefore increases. Thus a propeller governor tends to keep engine rpm constant, and a propeller equipped with a governor is termed a constant-speed propeller. For a more detailed discussion of the fundamentals of governor operation, see paragraph 27. Descriptions of specific types of governors are given in the section on the propeller with which the governor is used.

c. In studying the various types of controllable propellers, the mechanic should not lose sight of the fact that the pitch-changing mechanisms, some of which are rather complicated, have this one purpose—*to change the blade angle*. If the mechanic understands the purpose of changing the blade angle, the study of propellers should be more interesting and understandable.

6. Stresses and vibration.—*a*. *Stresses*.—Propellers rotating at high speeds are subject to three general types of stresses: bending, tensile, and torsional, as shown in figure 11.

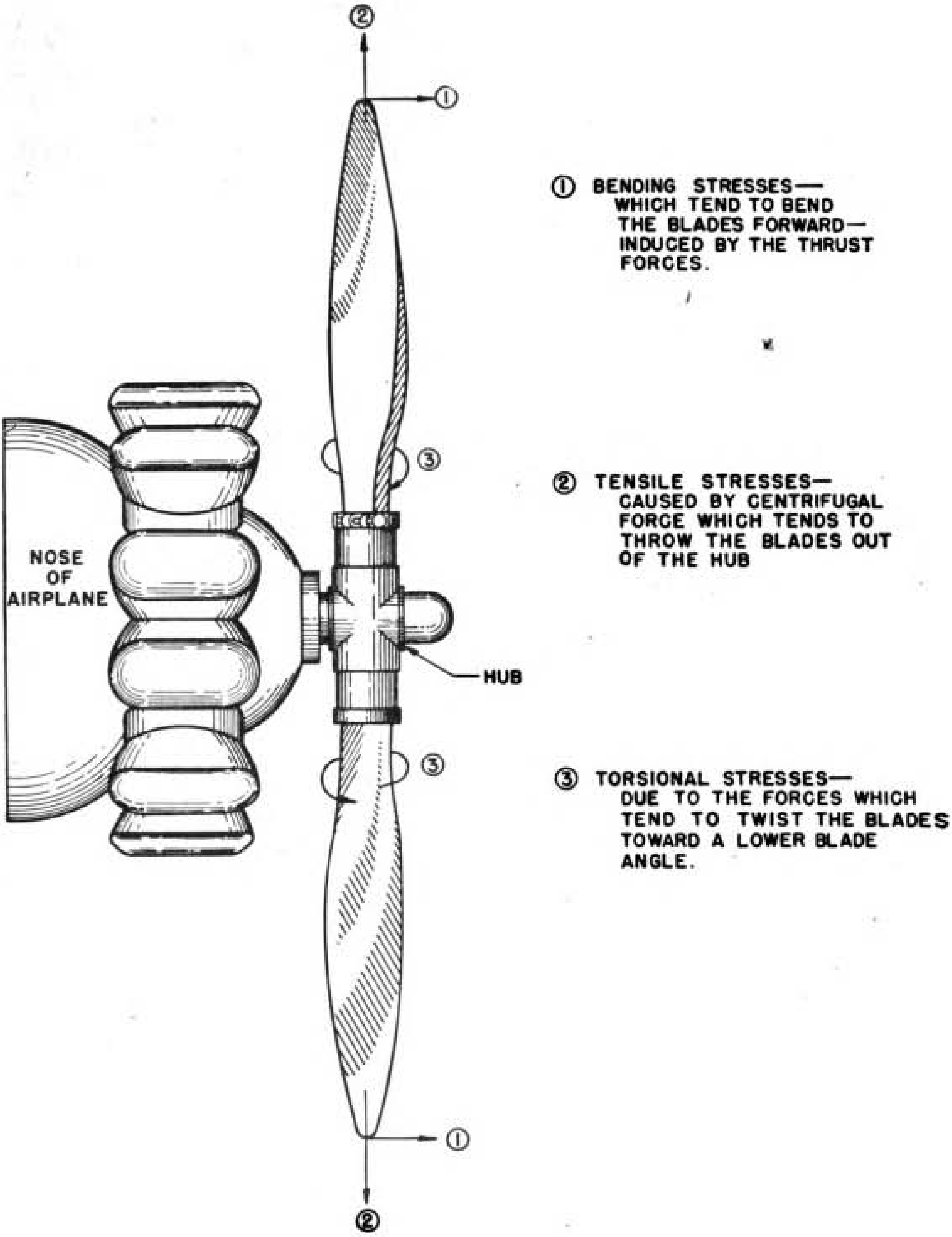


FIGURE 11.—Stresses on the blades of a rotating propeller.

(1) The bending stresses, induced by the thrust forces, tend to bend the blade forward as the plane is pulled through the air by the propeller. Other bending stresses, caused by air drag, are negligible.

(2) Tensile stresses are caused by centrifugal force, which is always tending to throw the blade out from the central hub. The

hub resists this tendency and the blades "stretch" a very slight amount.

(3) Torsional stresses are produced in rotating propeller blades by two twisting moments. One of these (due to the air reaction on the blades) is called the aerodynamic twisting moment. The other is due to centrifugal force which, during normal operation, tends to turn the blades to a lower angle. The latter is referred to as the centrifugal twisting moment. In some control mechanisms this centrifugal twisting moment is utilized to turn the blades to a lower angle when necessary.

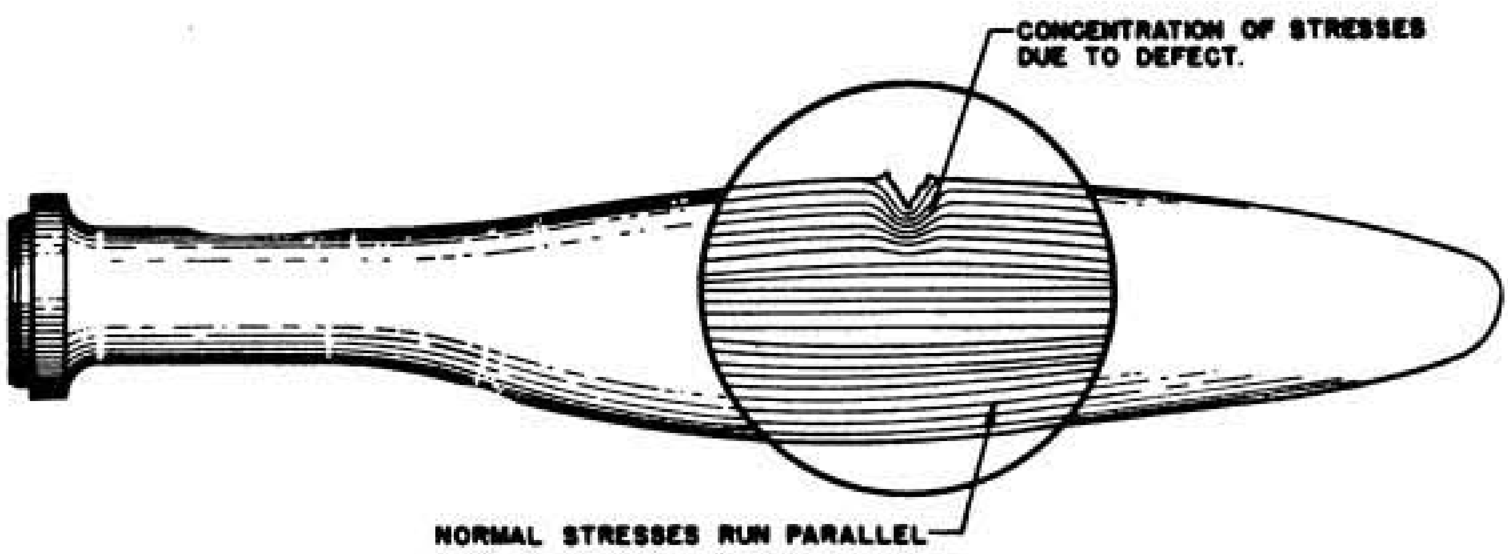


FIGURE 12.—Stress concentration due to a defect.

(4) *Cracks, nicks, dents, and other defects in blade.*—Normal forces on the blade cause normal stresses which in general run parallel along the blade throughout most of its outer length. A defect tends to concentrate a number of these parallel lines of stress at one point, causing stress concentration at this point, as shown in figure 12. The high localization of stress resulting from a small defect, such as a nick or a dent, may cause a small crack. This fracture of the metal will further aggravate the stress concentration, going from bad to worse, and will gradually spread until the entire propeller blade ruptures. The seriousness of defects in propeller blades and hubs, however small, cannot be overemphasized. The mechanic should take great care in examining the propeller for defects. If defects are found, they should be eliminated or the propeller replaced.

b. Vibrations.—Two kinds of vibration are often spoken of as propeller vibration. One of these is vibration *within* the propeller. This may be caused by engine explosion forces, aerodynamic forces. Vibration of this type is not readily observable without special instruments, but if too severe it may result in cracks (fatigue failures) particularly at nicks or sharp corners. For this reason the mechanic should make careful checks for defects in

blades and hubs at the periods specified in Technical Orders, or whenever checks are thought necessary. The other type of vibration associated with propellers is really vibration of the airplane caused by propeller unbalance. This unbalance of the propeller may be due to an unbalanced distribution of the material of the propeller or to unbalanced airforces of the blades.

(1) Some of the causes of material unbalance are: blades not properly positioned in the hub; improper placing of balancing weights; loose bolts, nuts or other parts; etc.

(2) Some of the causes of aerodynamic unbalance are: out-of-track condition of one or more blades; one or more blades of the propeller not set at the proper angle; irregular air flow, caused by icing or by some structural part of the airplane being too close to the plane of rotation of the propeller; etc.

(3) *Operation in "critical range".*—This is another cause of vibration. Each engine has a critical range of operation for each type of propeller with which it is combined. If the engine is operated within this range, severe vibration will occur. Obviously, continued operation of the engine within this speed range may result in serious damage to the engine and airplane and therefore should be avoided as much as possible.

7. Service use of propellers.—The service use of two-blade, fixed-pitch wood and metal propellers, and two- and three-blade, metal ground-adjustable propellers is almost entirely limited to a few primary trainer and liaison types of airplanes. Basic-trainer, advanced-trainer, and small transport airplanes use two- or three-blade controllable propellers made of either steel or aluminum alloy. Fighter, bomber, attack and large transport airplanes, because of their high horsepower, use the latest types of controllable propellers with three or more aluminum-alloy or steel blades. Some controllable propellers are designed so that a cannon may be fired through the propeller shaft.

SECTION II

WOOD PROPELLERS

8. General.—Over the period of aircraft development, a number of different materials have been used in the manufacture of pro-

pellers. For many years most propellers were made of wood, but the development of higher-horsepower engines created the need for propellers made of stronger, more durable materials. For this reason metal is now preferred for propellers to be used on engines of more than 300 horsepower. However, wood propellers are still used on lower-horsepower engines where great strength is not required. These wood propellers are lighter and easier to manufacture, and have less tendency to vibrate than metal propellers of the same power rating. In the Army Air Forces, most primary training and liaison types of airplanes are equipped with fixed-pitch wood propellers.

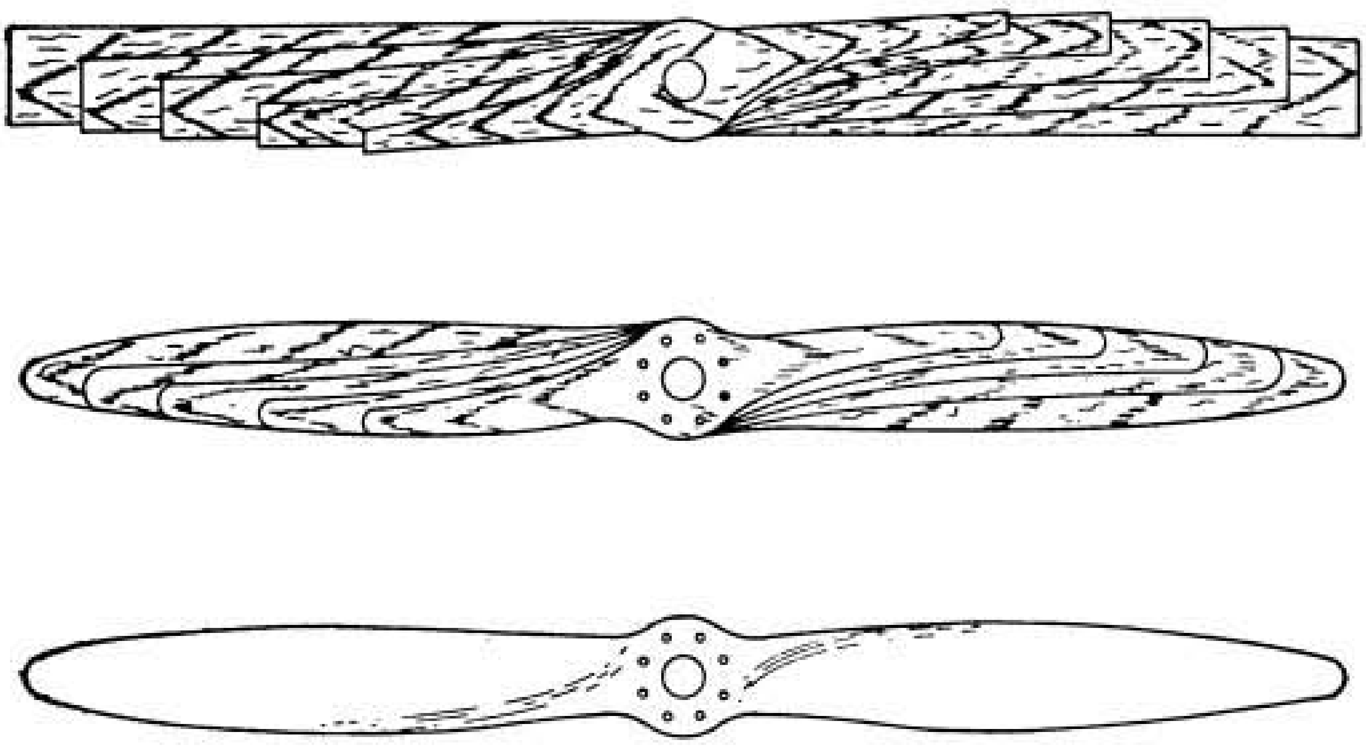


FIGURE 13.—Three stages in the construction of a wood propeller.

9. **Description.**—*a. Wood portions.*—A wood propeller is not carved from a solid block, but is built up of a number of separate layers of carefully selected and well-seasoned hard woods (fig. 13). Many woods, such as mahogany, cherry, black walnut, and oak, are used to some extent, but birch is the most widely used. Five to nine separate layers are used, each about ¾ inch thick. The several layers are glued together with a waterproof, resinous glue and allowed to set. The "blank" is then roughed to the approximate shape and size of the finished product. The roughed-out propeller is then allowed to hang for a week to permit the moisture content of the layers to become equalized. This additional period of seasoning prevents warping and cracking that might occur if the blank were immediately carved. Following this period, the propeller is carefully finished by hand. Templates and bench protractors are used to obtain the proper contour and blade angle at all stations. During the process the propeller is balanced.

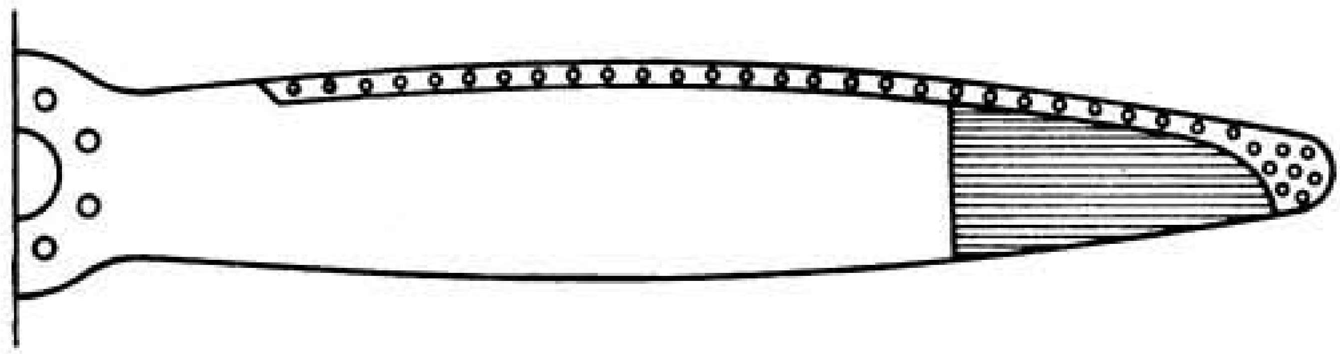


FIGURE 14.—Metal tipping on a wood propeller.

b. Tipping.—(1) During warm-up and run-up periods on the line and during take-offs and landings, propellers occasionally pick up small stones, bits of wood, and possibly small pieces of metal. These objects will injure any part of a blade that they strike, but since the tips have the least cross-sectional area and are traveling at a high rate of speed, the damage to these may be considerable. In addition, injury to a propeller on an airplane in flight may also be caused by insects, rain, snow, hail, and, when landing, by tall weeds. In order to prevent such injuries to the wood, the propellers have metal tipping that extends from the tips along the leading edges for a considerable distance toward the hub.

(2) Metal tipping may be of terneplate, monel metal, or brass. Stainless steel has been used to some extent. It is secured to the landing edge of the blade by means of countersunk wood screws and rivets. The heads of the screws are soldered to the tipping to prevent their loosening, and the solder is filed off to make a smooth surface (fig. 14). Since moisture condenses on the tipping between the metal and the wood, the tipping is provided with small holes near the blade tip to allow this moisture to drain away or be thrown out by centrifugal force. It is important that these drain holes be kept open at all times.

(3) In addition to the metal protective strip, 12 to 15 inches of the outer area of each blade is covered with fabric as further protection against being bruised in taking off and landing.

c. Finished.—Since wood is subject to swelling, shrinking, and warping because of changes of moisture content, a protective coating is applied to the finished propeller to prevent a too rapid change of moisture content. Two types of finishes are in use on wood propellers. The finish most commonly used consists of a number of coats of water-repellent, clear varnish. After these processes are completed, the propeller is mounted on a spindle and very carefully balanced. Small variations of balance are corrected by the addition of additionl varnish in the indicated places.

d. Attaching parts.—Several types of hubs are used to mount

wood propellers on the engine crankshaft. The propeller may have a forged steel hub that fits a splined crankshaft; it may be connected to a tapered crankshaft by a tapered, forged steel hub; or it may be bolted to a steel flange forged on the crankshaft. In any case, several attaching parts are required to mount the propeller on the shaft properly.

(1) Hubs fitting a tapered shaft are usually held on by a retaining nut which screws onto the end of the shaft. On one model, a lock nut is used to safety the retaining nut and to provide a puller for removing the propeller from the shaft. This nut screws into the hub and against the retaining nut. The lock nut and the retaining nut are safetied together with lock wire or a cotter pin. On newer models, a snap ring is used instead of a lock nut. When the retaining nut is backed off, it bears against the snap ring and starts the propeller from the shaft. This type is safetied through holes in the retaining nut and the shaft.

(2) Hubs fitting a splined shaft are held on by a retaining nut which screws onto the end of the shaft. In order to seat the pro-

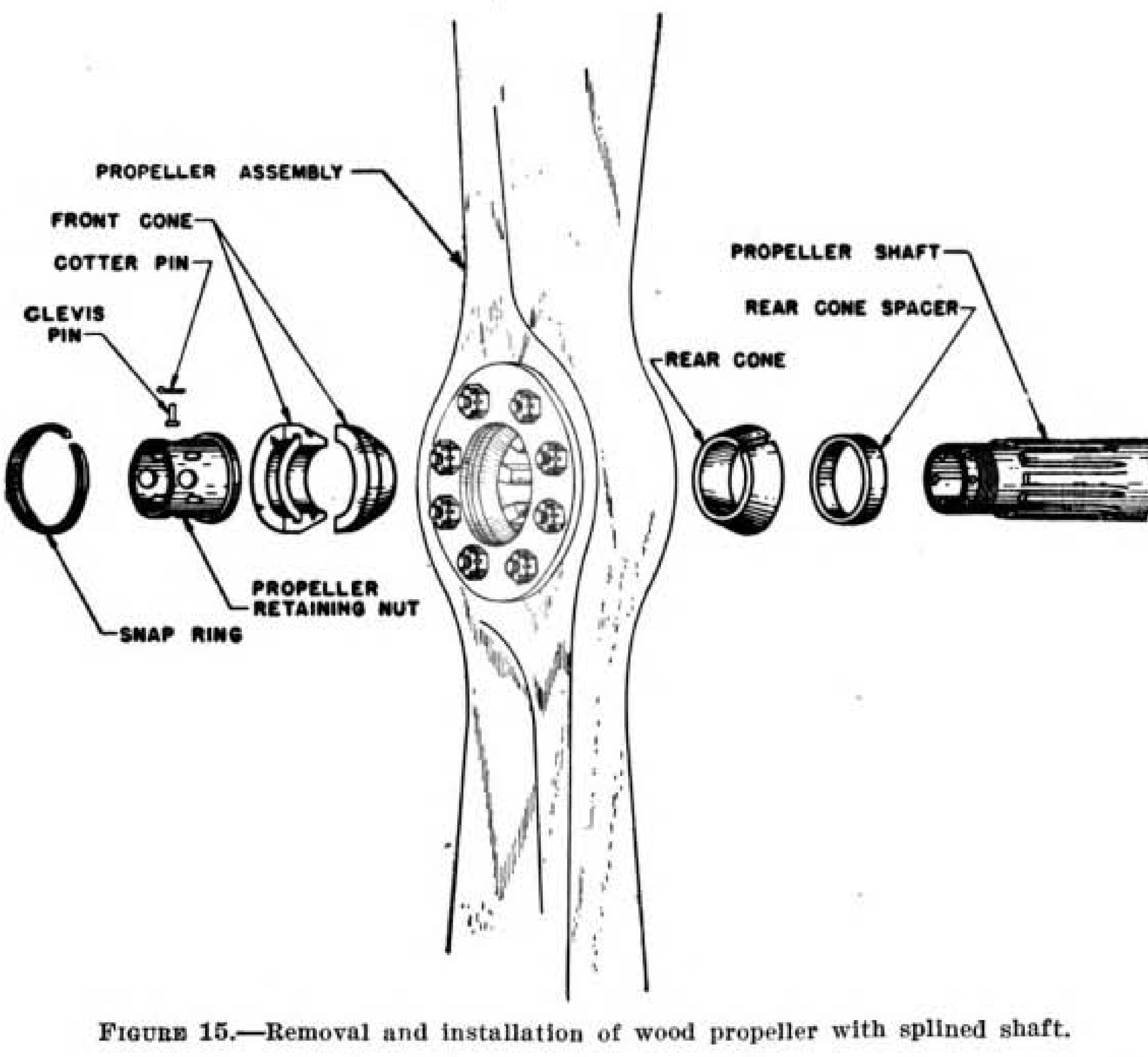


FIGURE 15.—Removal and installation of wood propeller with splined shaft.

peller properly on the splined shaft, a front and rear cone may be used. The rear cone is a one-piece bronze cone that fits around the shaft and against the thrust nut (or spacer), and seats in the rear-cone seat of the hub. The front cone is a two-piece, split type steel cone. It has a groove around its inner circumference so that it may be fitted over a flange of the propeller retaining nut. When the retaining nut is threaded into place, the front cone seats in the front-cone seat of the hub. A snap ring is fitted into a groove in the hub in front of the front cone, so that when the retaining nut is unscrewed from the propeller shaft, the front cone will act against the snap ring and pull the propeller from the shaft. Because the snap ring provides a puller for the propeller, it should never be removed when the splined shaft propeller is being removed from the shaft. One type of hub incorporates a bronze bushing instead of a front cone. When this type of hub is used it may be necessary to use a puller to start the propeller from the shaft. A rear-cone spacer is sometimes provided with the splined shaft propeller assembly to prevent the propeller from interfering with the engine cowling (fig. 15). Newer model hubs have a wide flange on the rear face. This eliminates the use of a rear-cone spacer.

(3) The principal purpose of the retaining nut is to hold the propeller solidly on the shaft. In some cases it also acts as a puller in conjunction with the snap ring in removing the propeller from the shaft.

10. **Removal.**—*a.* Removing propellers and hubs from tapered shafts is usually difficult, especially when they have been installed for a long time. The following method will be used to remove a propeller from a tapered shaft:

(1) Make certain that the ignition is OFF before starting removal; then remove the safetying lock wire or cotter pin.

(2) Remove, clean, and thoroughly lubricate the lock nut and the retaining nut.

(3) Thoroughly lubricate the threads of the hub and the shaft.

(4) Reinstall and tighten both nuts.

(5) Back out the lock nut one turn and back out the retaining nut until it seats lightly against the lock nut.

(6) Place the proper wrench on each nut so that the wrench handles are as nearly parallel as the position of the nuts will permit. Then align the handles by turning the retaining nut so that the two wrenches may be turned together.

(7) To prevent the crankshaft from turning, back out both nuts at the same time until the hub loosens from the shaft. Then

remove the nuts and other parts. A 2-foot length of 1½-inch pipe placed over the wrench handles is recommended to hold them together.

(8) If the hub cannot be loosened by normal force, a lead or brass hammer may be used for impact against the retaining nut, but only when necessary. In no case will harder material be used. When a hub cannot be removed in the foregoing manner, it will be carefully pressed off with suitable equipment.

b. To remove a propeller from an integral-hub, flange-type shaft, simply remove the hub bolt nuts, and then remove the propeller.

c. Propellers ordinarily are not difficult to remove from the splined shaft and when once loosened may be slipped off easily by hand.

(1) Remove the cotter pin and clevis pin securing the propeller retaining nut.

(2) Unscrew the propeller retaining nut. The front cone over the flange of the retaining nut will act against the snap ring in the hub and pull the propeller part way from the shaft.

(3) If the propeller cannot be loosened by normal force, remove the snap ring, nut, and front cone. Thoroughly clean the threaded portion of the nut and shaft. Lubricate the cone, nut, and shaft with clean engine oil, reassemble and apply sufficient force to unscrew the nut. If the propeller removed is to be replaced with a new one the rear cone and spacer remain with the engine.

(4) If the hub has a bronze bushing instead of a front cone, a propeller puller may be used to start the propeller from the shaft.

11. **Installation.**—Before installing any propellor, the inside of the hub and the shaft should be carefully wiped free of grease, dirt, grit, or any foreign particles. Any burrs or rough spots which might prevent the hub from slipping all the way on the shaft must be carefully removed with a fine file or handstone. A thin coating of light engine oil should be applied to the shaft before the propeller is installed.

a. The procedure for installing a propeller on a tapered shaft depends on the type of hub. In any case, step (1) below will apply. If a front cone and snap ring are used, the procedure described in *c* below will be followed. If a lock nut is used the procedure is as follows:

(1) Lift the propeller into position and after making sure that the key on the shaft lines up properly with the keyway of the hub, slide the propeller well back on the shaft. The hub should not bind or jam as it slides on the tapered shaft.

(2) Screw the retaining nut on the end of the shaft. A shoulder on the retaining nut bears against a shoulder in the hub and forces the hub on the shaft. For final tightening, *use the proper wrenches with no additional leverage.*

(3) Screw the lock nut into the hub. The lock nut has a fine thread, and care should be exercised in starting it in order to prevent cross threading. Pull it up tight but not as tight as the retaining nut, making sure that one of the locking-wire holes lines up with a hole in the retaining nut.

(4) Secure both the retaining nut and the lock nut with lock wire or a cotter pin.

b. Propellers are installed on integral-hub flange type shafts in the following manner:

(1) Place the propeller on the stub shaft.

(2) Make sure the threads on the bolts are free from metal clips and other foreign matter, and coat with light engine oil.

(3) Insert bolts in holes so that the nuts will be on the front face of the propeller when possible. Use a soft-headed hammer, if necessary, to drive bolts through the hub.

(4) Put on hub-bolt nuts and draw up evenly, a little at a time moving back and forth across the hub from one nut to another. This will help prevent throwing the propeller out of track and pitch.

(5) For final tightening, use a torque wrench to tighten the nuts with the force recommended in Technical Orders for the particular models of propeller, hub, and airplane. It is important that the nuts are not tightened beyond the recommended value, in order that the surface of the wood propeller hub will not be fractured.

c. The procedure for installing a propeller on a splined shaft is as follows:

(1) Install the rear-cone spacer (if used), and the rear cone on the propeller shaft.

(2) Matching the wide groove of the hub with the wide spline of the shaft, slide the propeller well back against the rear cone.

(3) Assemble the front cone onto the retaining nut, and screw the nut onto the propeller shaft. For final tightening, use a 3-foot bar through the holes in the nut. Hammering on the bar should be avoided. Do not tighten too tightly.

(4) Install the snap ring into its groove in the hub.

(5) Safety the retaining nut with a clevis pin and a cotter pin. A washer will be placed under the cotter pin on all propeller retaining nuts having elongated locking holes.

12. **Inspection and maintenance.**—At the periods specified in Technical Orders, the following inspections and maintenance will be performed on wood propellers:

a. Wood portion.—The wood portion of wood propellers will be carefully checked for any kind of defect. Possible defects are cracks, bruises, scars, warp, oversize holes for the hub and retaining bolts, evidence of glue failure and separated laminations, sections broken off, and defects in the finish. Some of the defects in the wooden portion may be repaired. Small cracks parallel to the grain of the wood in any lamination except the outside one may be filled with glue. The glue should be thoroughly worked into all portions of the cracks, dried, and then sanded smooth and flush with the surface of the propeller. When advisable, appreciable dents, scars, etc., having surfaces or shapes that will permanently hold a filler and will not induce failure, may be filled with a mixture of the proper glue and clean, fine sawdust. This mixture will be thoroughly worked and packed into the defect, dried, and then sanded smooth and flush with the surface of the propeller. A wood propeller having any of the following defects will be condemned:

(1) A crack, break, or deep cut across the grain of the wood.

(2) A comparatively long, wide, or deep cut or crack parallel to the grain of the wood.

(3) Separated layers of wood.

(4) An excessive number of screw or rivet holes.

(5) Bullet holes.

(6) Oversize hub or bolt holes.

(7) A bad warp.

(8) A fairly large portion of wood missing.

(9) Wear or damage obviously beyond economical repair.

b. Finish.—Clean the propeller with soap and water or other suitable solvents that will not affect the varnish or enamel, and inspect the condition of the finish. If the finish is in fairly good condition, touch up scratches and worn places with varnish. If the propeller contains quite a number of touched-up places, it should be sent to the repair shop for complete refinishing.

c. Fabric.—Inspect the fabric covering the tip of the blade. A tear or large loose spot in the fabric must be repaired immediately. Loose fabric will expose bare wood to weathering, causing absorption of moisture and development of further defects.

d. Tipping.—The tipping will be inspected for looseness or slipping, separation of soldered joints, distortion, loose screws and rivets, breaks, cracks, corrosion, and other defects. The drain holes in the tip should be checked to see that they are open. Screws

will be replaced along the metal tipping when the solder shows indication of cracking. Cracks in the narrow necks of metal between pairs of lobes of the tipping are to be expected and are not considered defects. Cracks which extend completely across straight tipping are not considered defects *if they do not enter screw or rivet holes.* All other cracks are defects and will be repaired. When it cannot be economically and properly repaired, tipping will be replaced, provided the general condition of the propeller warrants new tipping.

e. Hubs and attaching parts.—(1) The propeller hub and attaching parts will be inspected for cracks, galls, bends, cuts, nicks, corrosion, and other failures. Corrosion, and the raised points of galls, nicks, and scores, will be removed by careful filing, hand stoning, and lapping. However, this work will not be performed unless it can be accomplished economically, and will not induce scoring and galling. Propeller hubs and attaching parts having any of the following defects will be condemned:

(*a*) Corrosion, galls, or scores that cannot be removed as outlined above.

(*b*) A crack of any nature.

(*c*) A bend of any nature.

(*d*) Damage to the threaded portions.

(*e*) Misfitting due to oversize or undersize dimensions.

(*f*) Damaged or oversize splines.

(2) Propeller hubs on which the plating has worn off will be replaced and shipped to the depot for plating.

f. Checking hub nuts and retaining nut for looseness.—(1) Use an open-end wrench to check the hub nuts for looseness. If the nuts can be turned with normal force, remove the cotter pins and use a torque wrench to tighten them to the proper setting as specified in Technical Orders. Replace the cotter pins.

(2) The check of the propeller retaining nut will be made with the proper wrench, and the nut will be tightened as required and properly secured. If repeated tightening of the propeller retaining nut is necessary to remain the proper tightness, the propeller will be removed and the cause ascertained.

g. Correcting out-of-track condition.—The out-of-track allowance for wood propellers is $\frac{1}{16}$ inch. Slight out-of-track may be caused by unequal tension of the hub bolts. In such cases, the trouble can be remedied by tightening the bolts evenly and uniformly. As much as $\frac{3}{8}$ inch out-of-track at the tips may be safely corrected by placing shims of paper or other suitable lightweight material between the propeller and the inner hub flange. The cor-

rection may be accomplished with the propeller installed in the airplane.

h. Operational precautions.—(1) On installations which require hand cranking, give the propeller a rotary motion. Avoid pulling forward on the propeller, particularly if it is the type that has a thin blade section.

(2) Whenever possible, avoid opening the engine throttle while the airplane is standing or in motion on loose gravel, cinders, or mud. Particles picked up by the propeller or thrown against it by the wheels may cause serious damage.

(3) Wood propellers should always be placed in a horizontal position when the airplane engine is stopped for any length of time. If the propeller is exposed to the weather, it should be covered with a waterproof cover.

SECTION III

GROUND-ADJUSTABLE PROPELLERS

13. **General.**—The ground-adjustable propeller consists of two or more blades and a split hub. The propeller is non-controllable and, as the name implies, can be adjusted only while on the ground. At the time of assembly the blades are set at an angle that is fairly efficient for all service conditions. The proper angle for installation on a particular engine and airplane is determined by flight tests and is specified in Technical Orders. Since the advent of controllable propellers, the use of the ground-adjustable propeller has been confined almost entirely to the primary training type of airplanes.

14. **Description.**—There are two types of ground-adjustable propellers. One type has aluminum-alloy blades; the other, solid steel blades.

a. Aluminum alloy blade type.—(1) As a means of securely attaching the blades to the hub and in order to take up centrifugal force on them, shoulders are machined on the shank of aluminum-alloy blades (fig. 16). A hole is drilled in the center of the blade butt. Lead may be added to or removed from this hole to balance the propeller.

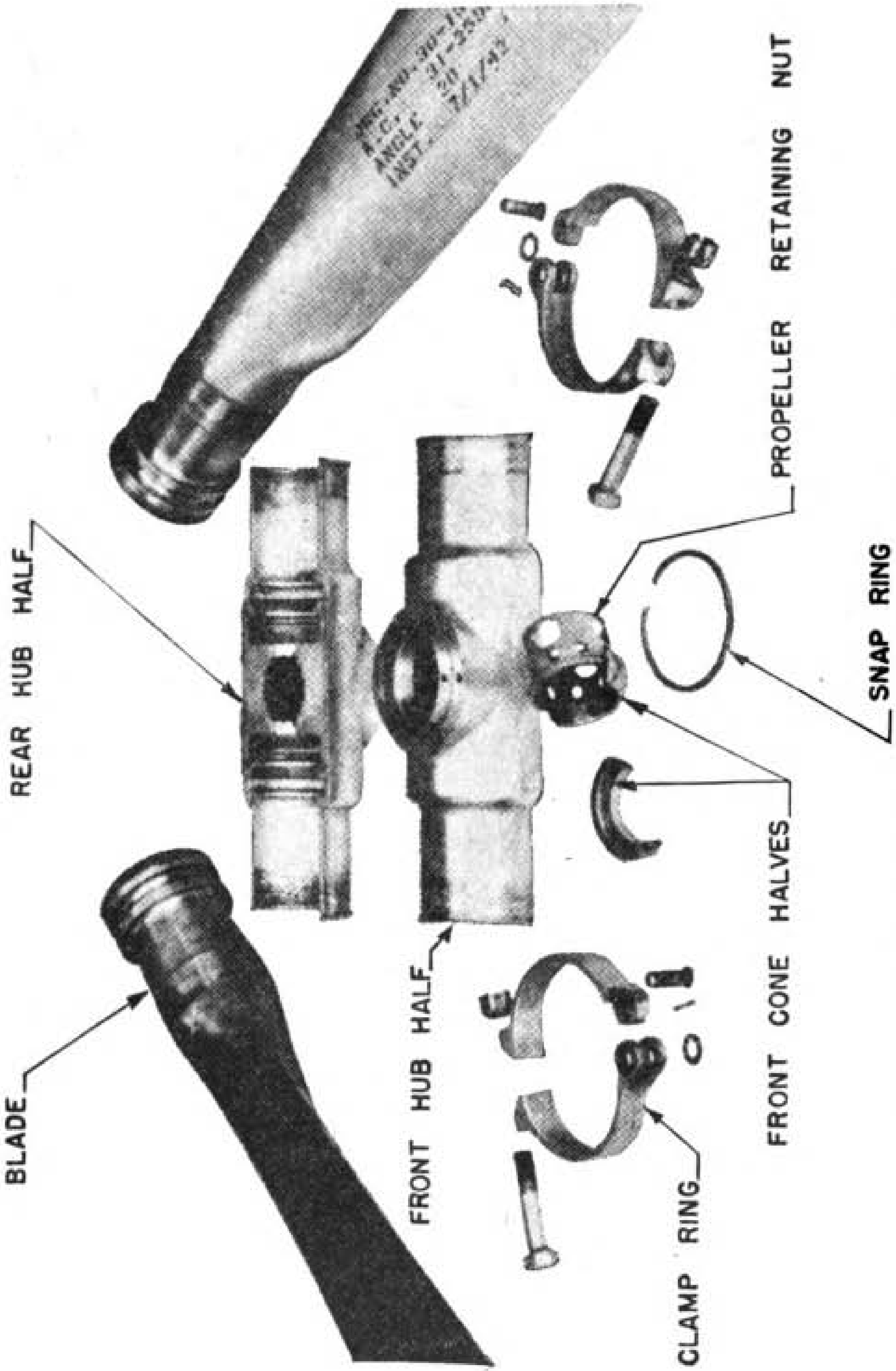


FIGURE 16.—Aluminum-alloy-blade ground-adjustable propeller assembly.

(2) The hub is made of chrome-vanadium steel and is cadmium-plated to prevent corrosion. It is of the split type. Recesses are machined in the matching halves to receive the blade shoulders. The hub halves are held together over the blade shanks by means of clamp rings located at each end of the hub. With the blade shoulders seating in the hub recesses and the clamp rings against the shoulders near the ends of the hub, the nuts on the

clamp ring bolts are tightened and the hub halves are drawn together. In this way the blades are retained in the hub, and are prevented from turning from the angle at which they are set.

(3) The hub is splined to fit a splined propeller shaft. Cone seats are machined in the front and rear of the hub, and a front and a rear cone are provided to seat the propeller properly on the shaft. A groove to receive a snap ring is machined in the front hub half directly ahead of the front-cone seat. The front cone is of the split type, and is grooved to fit over a flange on the propeller retaining nut (fig. 16). When the nut is unscrewed from the propeller shaft, the front cone will act against the snap ring to pull the propeller from the shaft. Thus the purpose of the snap ring is to aid in pulling the propeller from the shaft. It is sometimes necessary to use a rear-cone spacer with this propeller. It is placed behind the rear cone to locate the propeller properly on the shaft.

b. Solid steel blade type.—(1) Each solid steel blade is machined from a single heat-treated steel forging. Because of a special airfoil design, the sections are thin and the shank of the blade is small in comparison with the aluminum-alloy blade. The butt end of the blade is drilled out to reduce weight, and to provide for balancing of the propeller assembly. A shoulder is machined on the blade butt.

(2) The hub is of the split type and is manufactured from high-strength steel. The clamp rings used with this type of propeller are made in one piece and therefore do not have hinge pins. A front and rear cone, snap ring, and retaining nut are also provided with this propeller (fig. 17).

15. Removal and installation.—*a. Removal.*—The procedure of removing a ground-adjustable propeller from the propeller shaft is as follows:

(1) Before beginning the removal of *any* propeller, check to see that the ignition switch is in the OFF position.

(2) Remove the clevis pin and cotter pin which safety the retaining nut to the propeller shaft.

(3) Loosen the retaining nut and unscrew it from the shaft. The front cone acting against the snap ring will pull the propeller forward.

(4) Remove the snap ring, retaining nut, and front cone. Take care that the halves of the split front cone do not fall off the retaining nut to the ground. The slightest defect in a front cone will be cause for replacement.

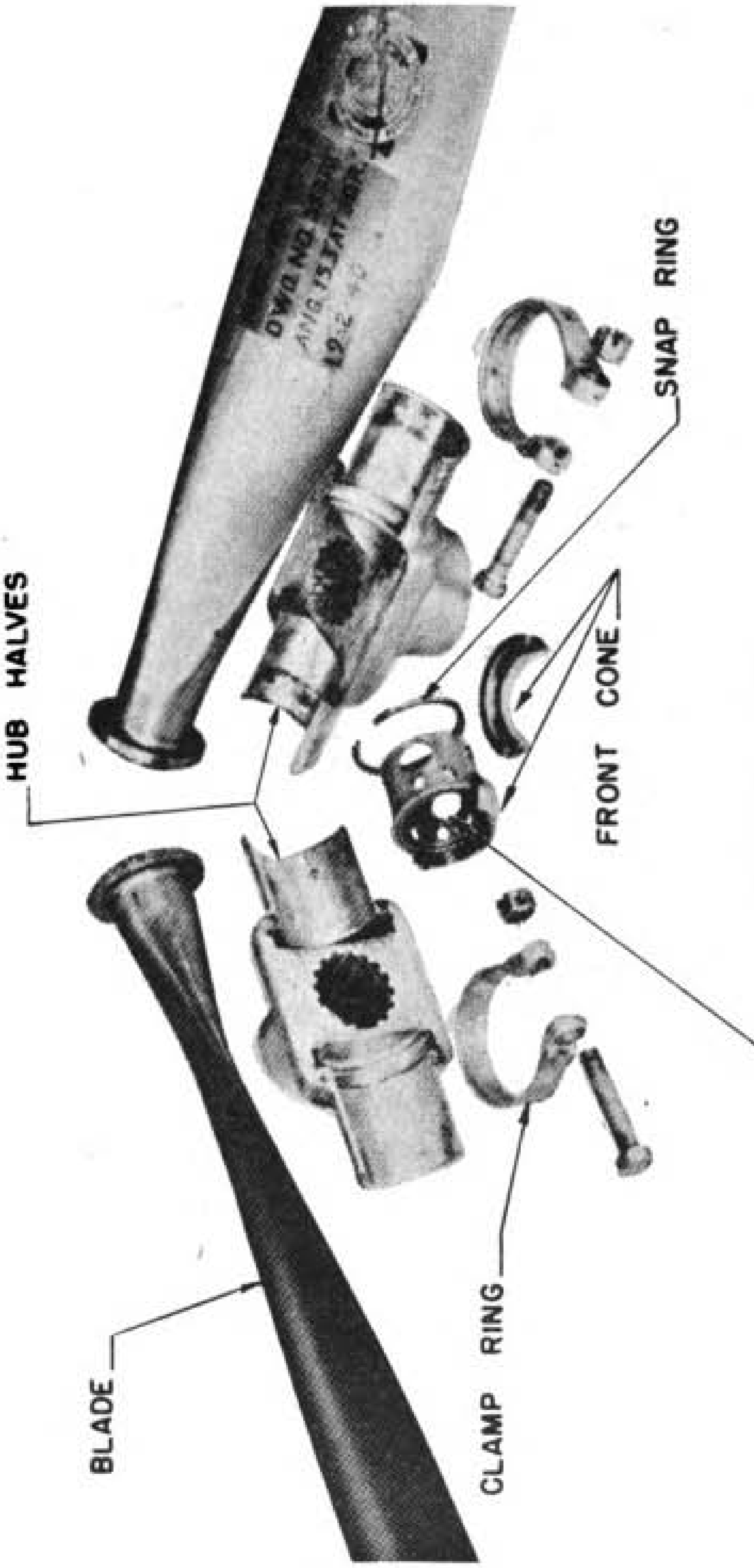


FIGURE 17.—Steel-blade ground-adjustable propeller assembly.

(5) Using a hoist, carefully remove the propeller from the shaft. Avoid scraping over the tops of the shaft threads.

(6) Remove the rear cone and the rear-cone spacer. The removal of the propeller is thus completed (fig. 18).

b. Installation.—Before installation, all parts will be examined for damage and defects, and checked for proper fitting. The pro-

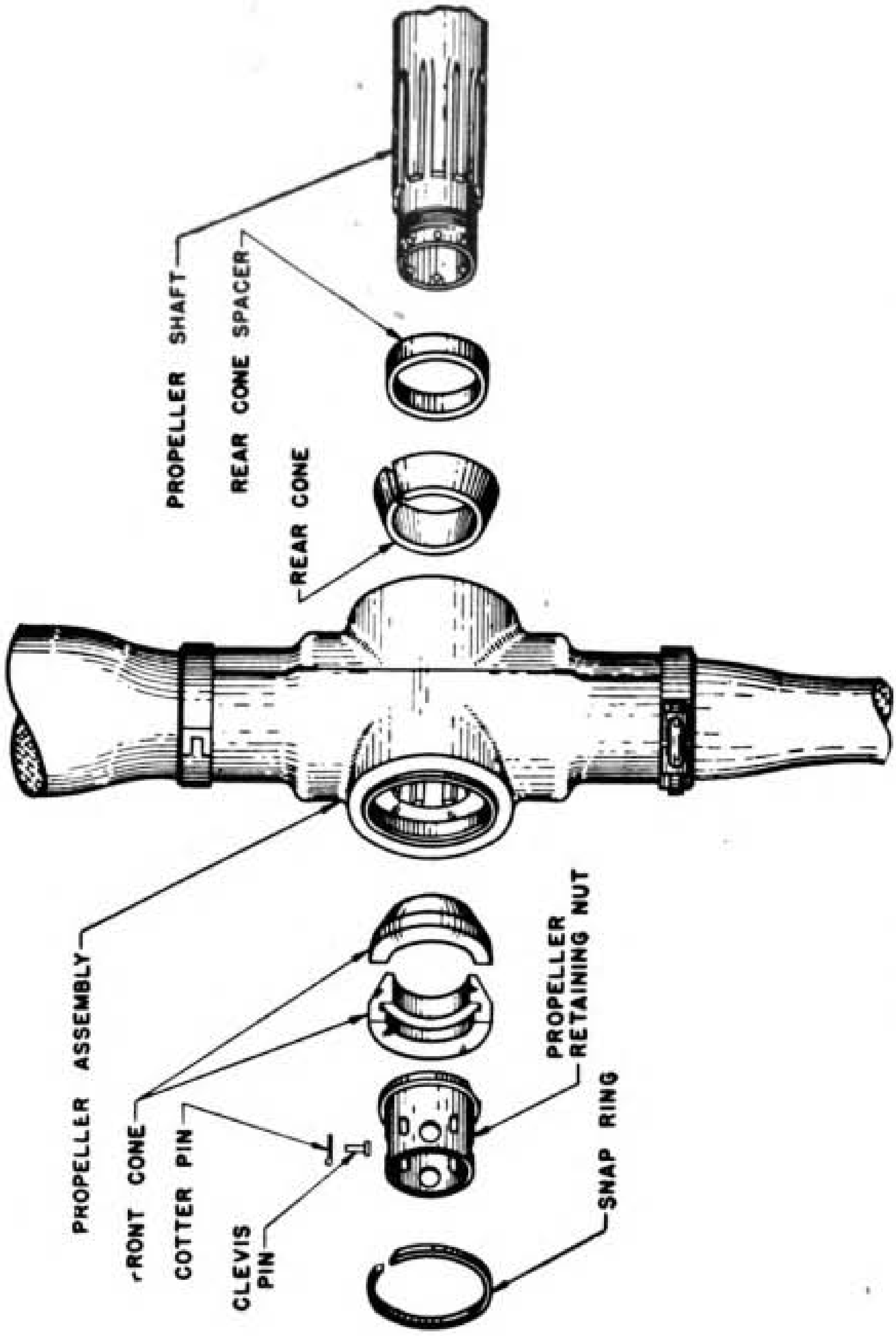


FIGURE 18.—Removal and installation of the ground-adjustable propeller.

peller shaft will be checked for defects, and all defects repaired. All internal surfaces, except the threaded portion of the propeller retaining nut, the rear cone, and the rear-cone seat will be coated with clean engine oil to provide lubrication and prevent corrosion. These surfaces include hub splines, the front cone and front-cone seat, and the propeller-shaft splines. The rear cone and rear-cone seat will be left dry. The installation may then be accomplished as follows:

(1) Place the rear-cone spacer, and then the rear cone, on the propeller shaft.

(2) Using a hoist, carefully slide the propeller on the shaft,

matching the master spline of the shaft with the wide groove of the propeller. The propeller should be pushed well back against the rear cone. Care should be exercised to prevent damage to the threads of the shaft. If difficulty is encountered in sliding the propeller on the shaft, the hub halves should be checked for alignment. If this does not reveal the trouble, check the splines of the shaft and the hub for burrs. At no time should force be used to install the propeller on the crankshaft.

(3) Coat the threads of the propeller retaining nut with thread lubricant.

(4) Assemble the two halves of the front cone on the flange of the retaining nut, and screw the retaining nut on the shaft. For final tightening, exert approximately 175 pounds of force on the end of a 4-foot bar. A safetying hole in the retaining nut should line up with a hole in the propeller shaft. If it does not, the nut will be backed off and tightened again until the holes do align.

(5) Insert the snap ring into the groove in the hub.

(6) Safety the retaining nut by installing a clevis pin of correct size in the aligned holes of the retaining nut and the shaft. The pin is installed with the head toward the center of the shaft, so that centrifugal force will tend to keep it in place when the propeller is rotating.

(7) Safety the clevis pin with a cotter pin.

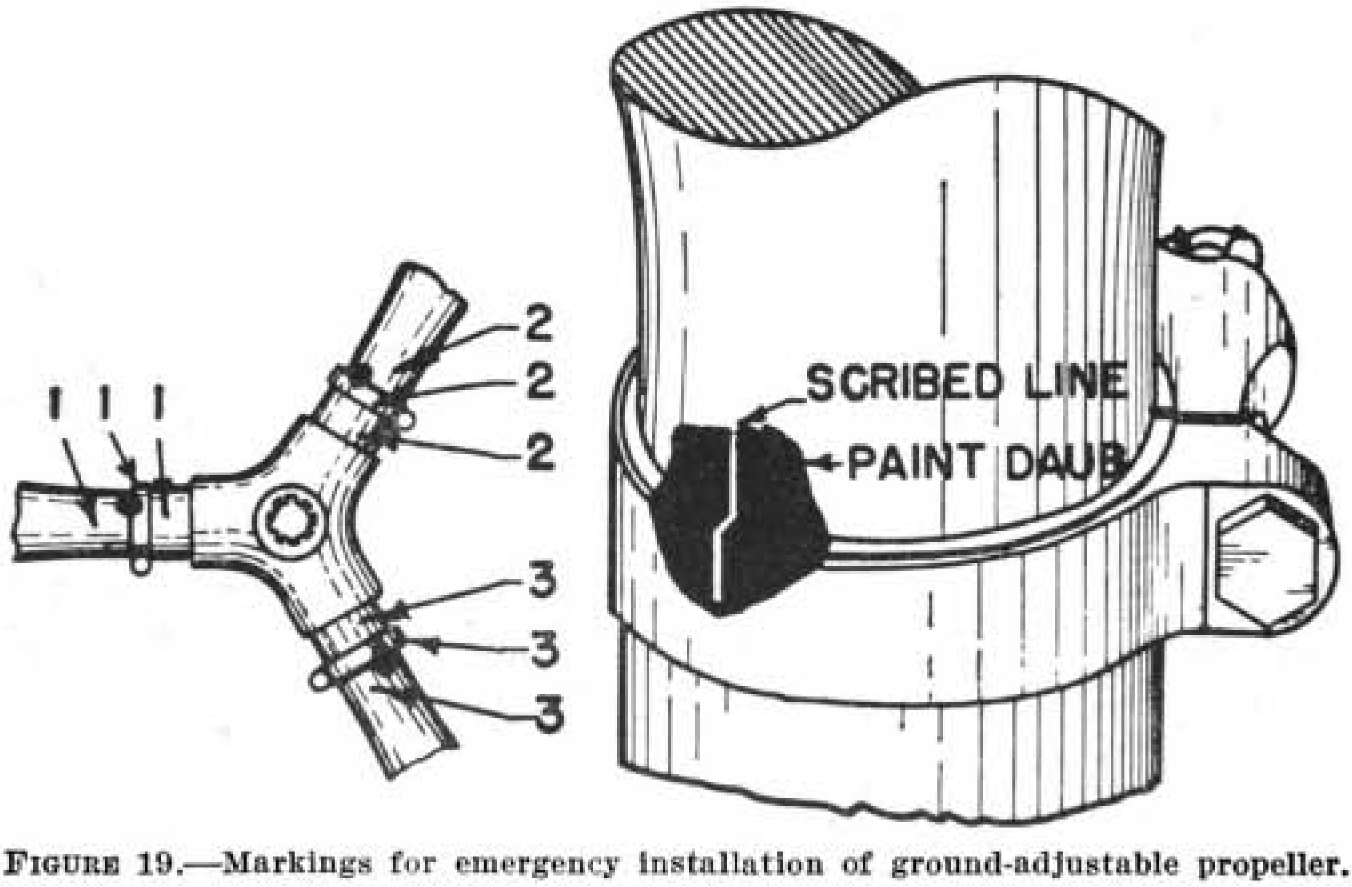


FIGURE 19.—Markings for emergency installation of ground-adjustable propeller.

c. Emergency installation.—It is sometimes necessary to ship a propeller, for installation on an airplane, to a point where balancing facilities are not available, and the size of the propeller may

make it impracticable to ship it assembled. In such a case, the propeller is completely assembled and tracked, blade angles are set, and the propeller is balanced prior to shipment from the air depot shops. Each blade, blade socket, and clamp ring is numbered as shown in figure 19. A small area is painted on each blade near the hub, so that the painted area extends across the end of the hub and on to the clamp ring. When the paint has dried, a reference line is scribed so that the exact position of each blade in the hub and also the position of the clamp ring can be visibly determined. The propeller is then disassembled and packed for shipment. When the propeller arrives at its destination, the blades are assembled in the hub, care being taken to assemble each blade and clamp ring to the correspondingly numbered blade socket. The procedure for installing a propeller shipped and assembled in this manner is as follows:

(1) Start the propeller on the shaft. If the hub binds when partly on the shaft, it may be necessary to loosen the clamp rings and shift the front half of the hub until it also slides on to the shaft.

(2) Without tightening the clamp rings, draw the propeller retaining nut up snugly but not tightly.

(3) Turn the propeller until one blade is vertically downward. Tap the shank of that blade with a rawhide mallet while pulling down on the blade. Align the scribed lines marked on the blade, blade socket, and clamp ring. Tighten the clamp ring using the proper torque, and then safety the clamp-ring nut. Repeat this operation for each blade.

(4) Check all blades, clamp rings, and blade-socket numbers for correct assembly, and check the alignment of scribed marks.

(5) Tighten and safety the retaining nut.

(6) The balance and blade-angle settings of the propeller should be accurately checked with the proper equipment at the first opportunity.

16. Inspection and maintenance.—Besides the general inspections and repair covered in section XI, certain inspections and repairs are performed on ground-adjustable propellers only.

a. Safetying of ground-adjustable propellers.—A visual inspection of the safetying should be made. On a ground-adjustable propeller having aluminum-alloy blades, safetying includes the retaining nut, cotter pin, and clevis pin, and the cotter pins for the clamp-ring nuts and the clamp-ring hinge pins. The clamp rings of a ground-adjustable propeller with solid steel blades do not have hinge pins; otherwise the safetying is the same.

b. Correcting interference with cowling.—Any interference between the clamp-ring bolts and nuts and the engine cowling is corrected before flight by adding a spacer behind the rear cone. Under no circumstances will the position of the clamp rings be changed, for any change in their position will put the propeller out of balance.

c. Retaining nut.—The retaining nut is checked for looseness in the following manner:

(1) Remove the retaining-nut cotter pin and clevis pin.

(2) Insert a 4-foot bar into the retaining nut. A force of 175 pounds applied on the end of the 4-foot bar is sufficient to check the retaining nut for looseness. The force is applied steadily; jerking on the bar should be avoided. Do not use additional leverage or force to make the check.

(3) Replace the retaining-nut clevis pin and cotter pin.

d. Clamp rings.—The clamp rings of a ground-adjustable propeller with aluminum-alloy or steel blades may be checked accurately with a torque wrench. If such a wrench is available, proceed as follows:

(1) Determine from Technical Orders the number of inch-pounds torque required for the clamp-ring nuts of the particular propeller and hub assembly. Set the wrench at this figure.

(2) Remove the cotter pin from the clamp-ring nut.

(3) With the torque wrench set to obtain the specified inch-pounds, check the nut for looseness.

(4) Safety the nut with a cotter pin.

(5) If a torque wrench is not available, use a leverage not to exceed 12 inches and a normal pull. If it is necessary to tighten these nuts with a wrench other than a torque wrench, care must be taken not to use excessive force, since this will cause unduly high stresses in the hub and clamp-ring bolts.

e. Hub halves.—If the rear half of the hub will go on the shaft while the front half will not, the hub halves are out of alignment and must be realigned. To realign the hub halves, loosen the clamp rings slightly and tap the hub with a rawhide mallet. This tapping allows the front half of the hub to align itself properly in relation to the propeller shaft, and will correct the condition. Great care should be exercised not to change the blade angle or the position of the clamp rings during this operation.

f. Blades.—The blades may be checked for proper angle by means of graduations on the end of the hub and the scribed line on the shank of the blade. The graduations should be used for routine check and emergency setting only. A propeller checking

plate or universal propeller protractor should be used to obtain an accurate check or setting.

g. Cone bottoming.—Ground-adjustable propellers should be checked for front- and rear-cone bottoming at installation and at any other time it is thought necessary. If the retaining nut has been tightened but the propeller remains loose on the shaft, the probable cause is front cone bottoming. Use the prussian blue check described in paragraph 78. In case the front cone is bottoming, it is corrected by the addition of a locally manufactured spacer behind the rear cone. In the event of rear-cone bottoming, $\frac{1}{16}$ inch is cut off the apex of the rear cone, or the cone is replaced with a new one.

h. Vibration.—Excessive vibration in the propeller is a serious condition and must be corrected before flight, or the propeller must be replaced. It may be due to one or more of several probable causes. If excessive vibration is present the airplane mechanic should—

(1) Check the blades for looseness in the hub.

(2) Check the hub for looseness on the shaft.

(3) Check the blade-angle settings.

(4) Check the propeller for track.

(5) If the above checks are found to be correct or within the specified tolerance and the necessary facilities are available, the propeller should be removed from the shaft and checked for balance.

(6) If the airplane mechanic cannot correct the condition, he should make a report to the proper authorities.

SECTION IV

HAMILTON STANDARD TWO-POSITION PROPELLERS

17. General.—*a. Advantages of two-position propeller.*—To prevent abuse of the airplane engine, it is necessary to set a fixed-pitch propeller so that the engine turns at its rated rpm with full throttle in level flight. As explained in section I, the result is a

loss of airplane performance in other attitudes of flight. With a controllable propeller this disadvantage is eliminated (fig. 21). The smaller the blade angle, the less will be the load on the blades of a propeller, and the faster will be the engine speed at a given throttle setting. The blades of a controllable propeller may be changed to a low enough angle to permit an engine to operate at its maximum rpm with maximum manifold pressure during take-off and climb. Thus the engine will develop its maximum rated horsepower when it is needed. At the same time, the blades may be changed to a higher angle during level flight to prevent abuse of the engine. The Hamilton standard two-position propeller was designed to meet these basic requirements of a controllable propeller (fig. 20). It has two blade-angle settings: the low-setting is a compromise for best take-off and climb; the high blade angle is

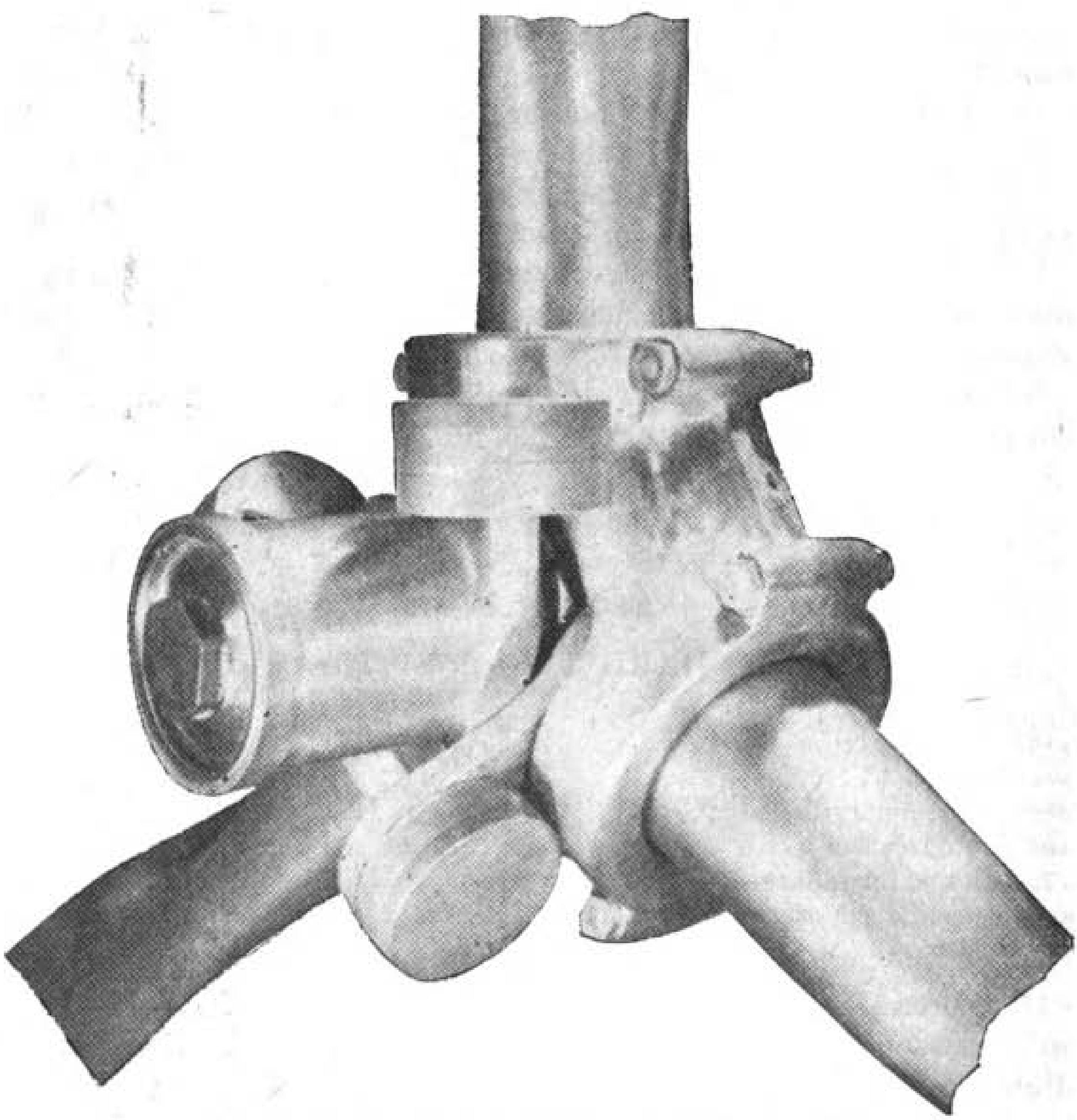


FIGURE 20.—Hamilton standard two-position propeller.

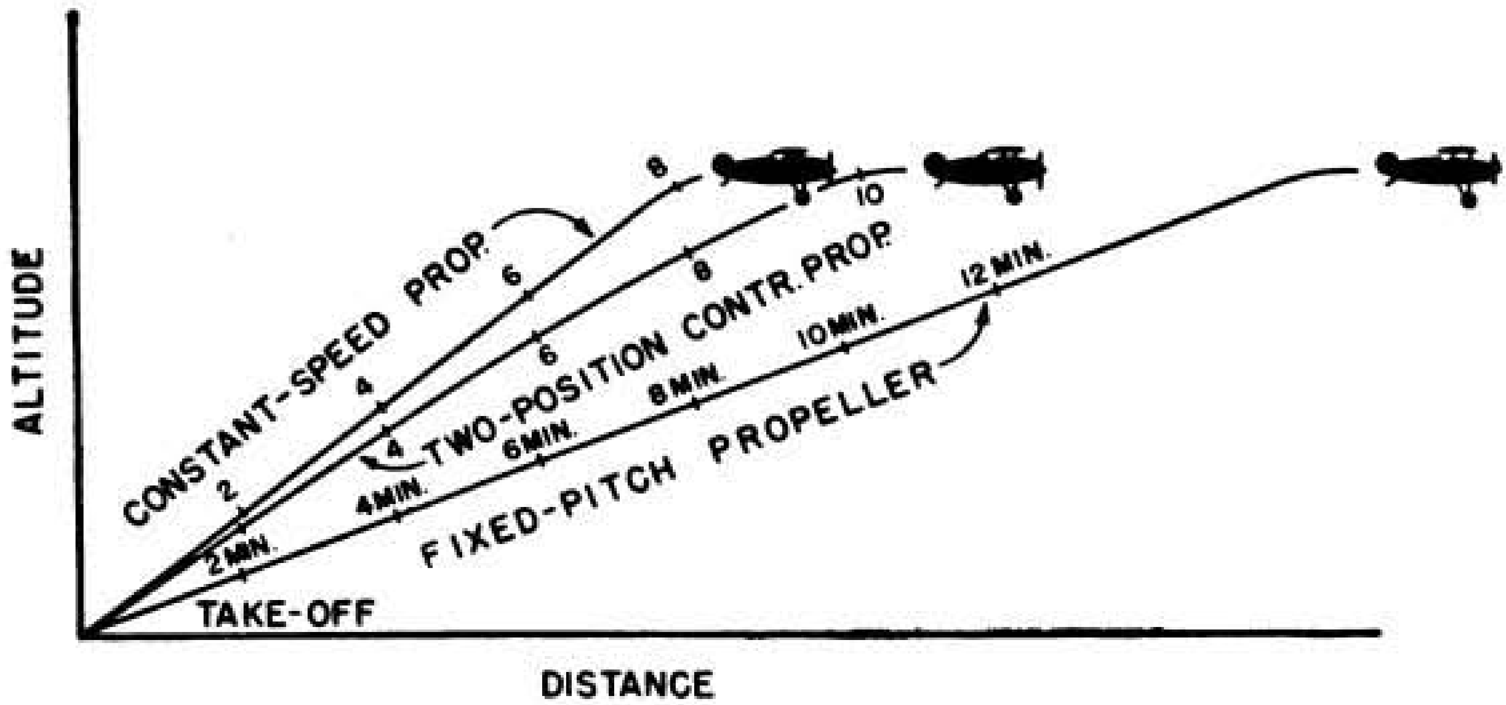


FIGURE 21.—Comparative performance of airplanes equipped with different types of propellers.

usually set for efficient operation during normal cruising conditions, depending upon the airspeed, altitude, rpm and cruising power at which a particular airplane will best operate.

b. Pitch-changing mechanism.—The pitch-changing mechanism of the two-position propeller is operated hydraulically by oil under pressure from the engine lubricating system. When this oil is directed by means of a control valve to the pitch-changing mechanism, it puts the propeller into low pitch for take-off and climb. To provide a means for putting the propeller into high pitch, counterweights are attached to the pitch-changing mechanism, and they rotate with the propeller assembly. They are attached to the blades by a mechanical linkage in such a manner that when centrifugal force causes them to fly outward (away from the axis of rotation), the blades will go to high pitch. When the control valve is turned so that the oil is drained from the propeller back to the engine crankcase, centrifugal force on the counterweights is great enough to overcome the natural tendency of the blades to turn to low pitch. The counterweights will therefore fly outward and the blades will be moved to high pitch. The two-position propeller has only these two blade-angle settings, full-low and full-high pitch; the blades cannot be stopped at an intermediate pitch.

18. Description.—Hamilton standard two-position propellers are made with either two or three blades. Following is a brief description of the principal units of this propeller:

a. Spider.—The foundation of the propeller is the spider. The heat-treated steel forging from which it is made is splined through the center to fit the propeller shaft. The spider arms are carefully machined to receive the blades (fig. 22). The spider is therefore

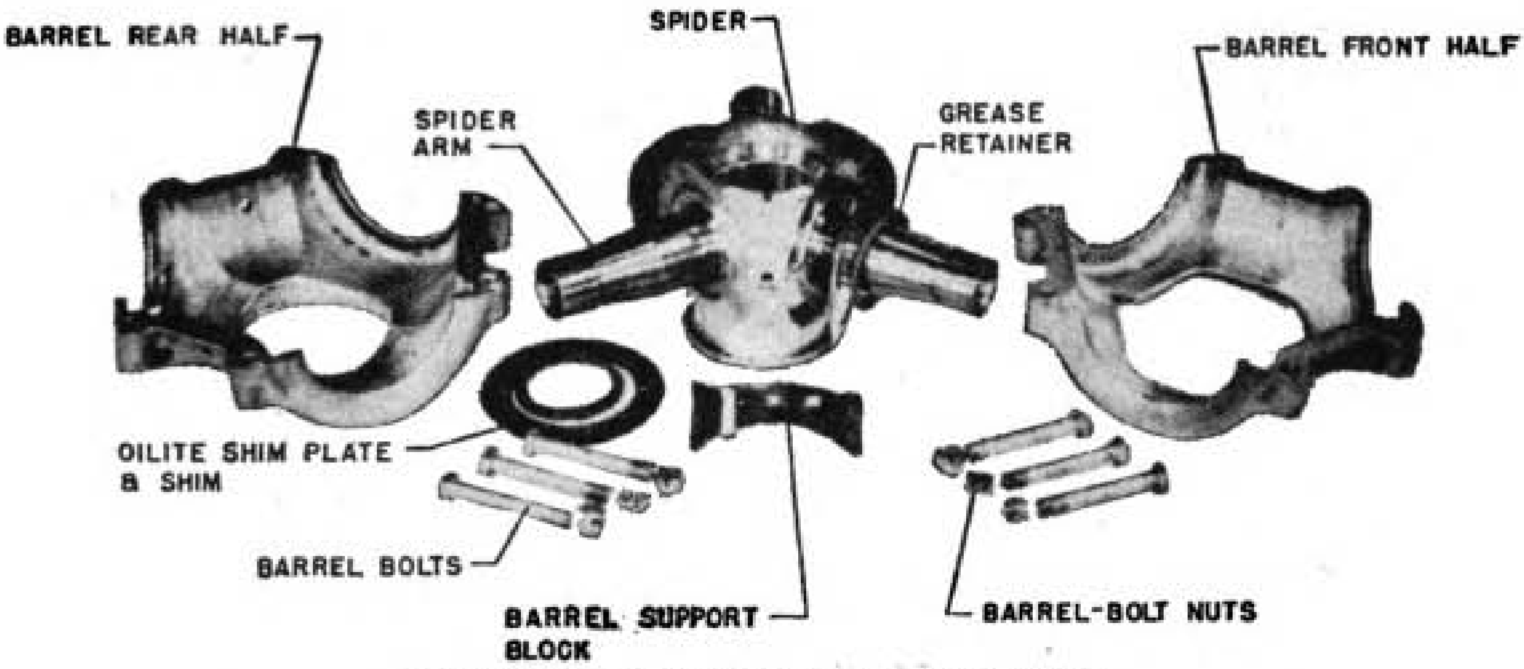


FIGURE 22.—Barrel and spider assemblies.

the means of transmitting the engine torque to the propeller blades, and must be of great strength to carry the principal torque and thrust loads on the blades. Some means is necessary by which the outside surface of the spider arms, on which the blade assemblies turn, may be lubricated when the propeller is fully assembled. This is provided by small passages that lead from the spider arms to grease fittings between the spider arms. The spider has cone seats machined at the front and rear of its splines. A groove to receive a snap ring is machined directly ahead of the front cone seat.

b. Barrel halves.—The barrel halves fit over the spider and the blade shoulders, and act to retain the blades to the central spider-and-barrel assembly. These barrel halves are made from a steel forging, and, to insure perfect matching, they are brought through

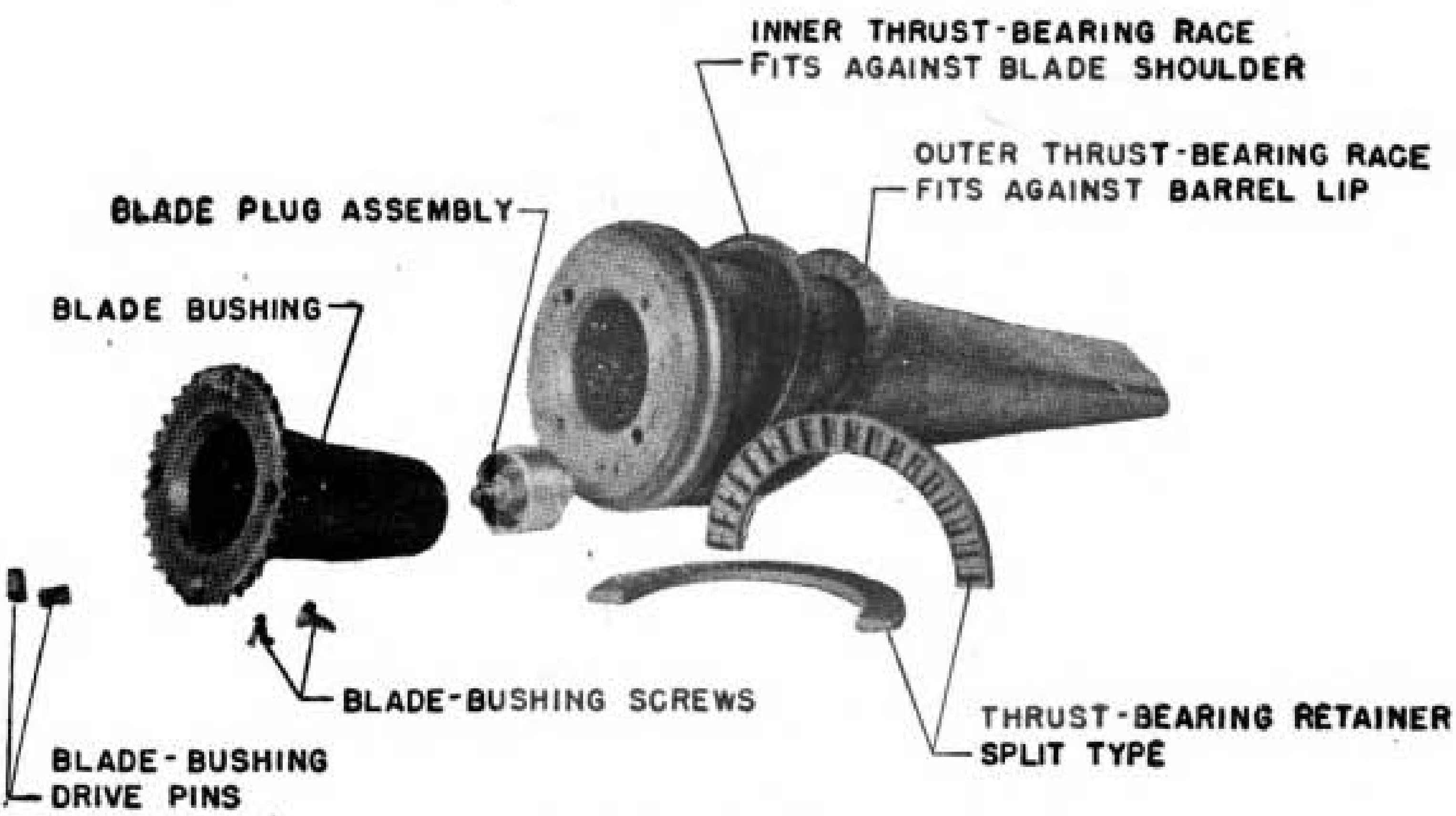


FIGURE 23.—Blade assembly.

the accurate machining processes as one unit. The barrel halves are held together over the spider and blade shoulders by barrel bolts. Micarta barrel-support blocks located between the spider arms support the barrel on the spider. The primary function of the barrel is to carry the centrifugal load of the blades.

c. Blade assembly.—Following is a description of the parts of the blade assembly:

(1) The blades are made from aluminum-alloy forgings, which are machined and ground to shape and then polished. The blade shank is hollow. A blade bushing of aluminum bronze is pressed tightly into the hollow end of each blade shank, and is held in place by two drive pins and two screws. An aluminum blade plug is pressed into the hollow shank, just beyond the end of the blade bushing. Its purpose is to prevent lubricant from filling the small end of the hollow shank. In addition it is provided with a stud on which washers are installed as a means of obtaining propeller balance. (fig. 23).

(2) A shoulder is machined on the shank of the blade to provide for blade retention. To permit the blades to rotate with minimum friction, a thrust-bearing assembly is placed around the shank of each blade and against the blade shoulder. This assembly consists of two steel thrust races which are made with the blade and cannot be removed from it. A split thrust-bearing retainer and roller

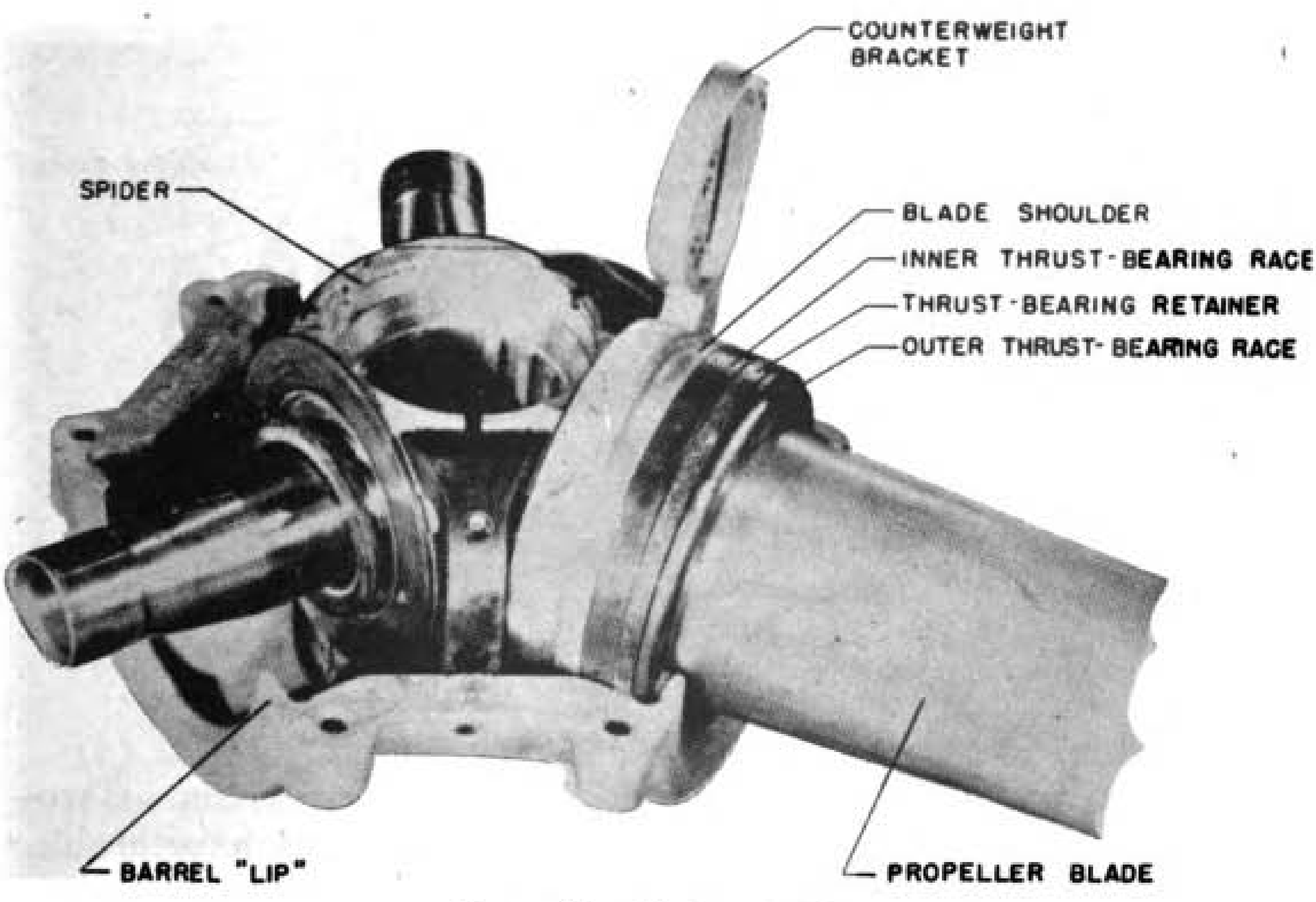


FIGURE 24.—Blade retention.

bearings are fitted between these races. The two halves of the bearing retainer may be replaced when necessary because of wear.

(3) The blade bushings and spider arms are carefully machined to provide a close fit between them when the blades are placed on the spider arms. As the barrel bolts are tightened, the "lips" of the barrel halves are pulled over the outer thrust races. The thrust-bearing assembly is thus held tightly between the barrel lip and the blade shoulder. The centrifugal force on the blade is transmitted through the thrust-bearing assembly to the barrel lip, and the blades are in this manner retained to the central spider-and-barrel assembly (fig. 24).

(4) A few other parts are required to complete the spider-and-barrel and the blade assembly. One of these is a spring-loaded, leather grease retainer, beveled on one side to fit snugly in a groove at the base of each spider arm (fig. 22). This grease retainer prevents grease from being thrown from between the blade bushing and the spider arm. To prevent the spider of the assembled propeller from galling, oilite shim plates are placed on the spider faces (fig. 22). These plates are made of a metal that absorbs and holds oil, so that they provide lubrication between the spider and the blade assembly. Some means is necessary to insure a reasonably tight fit of the blade assembly parts, which are held between the spider and the barrel. For this purpose, either laminated shims peeled to the required thickness or solid brass shims are placed between the shim plates and the spider faces.

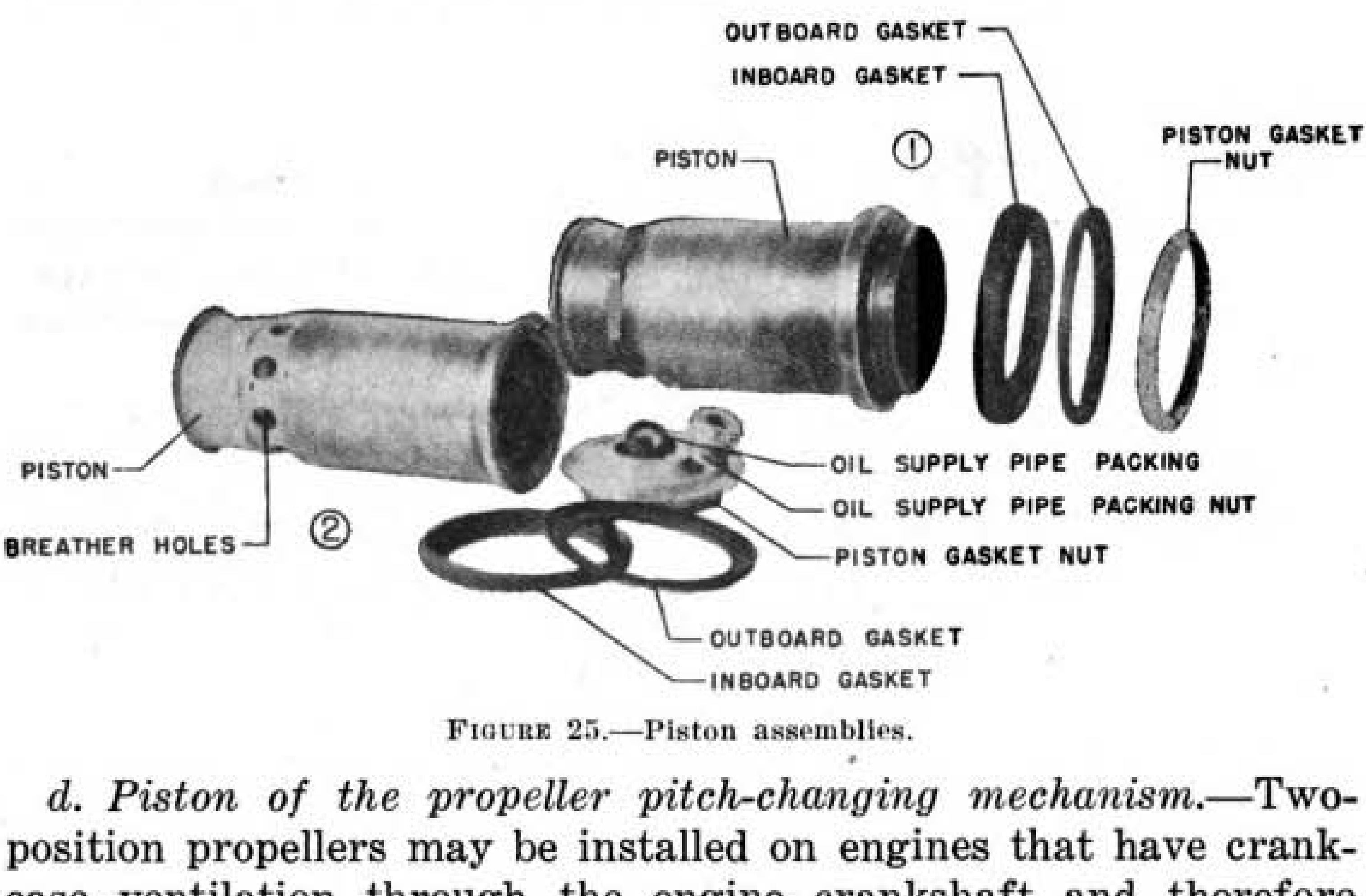
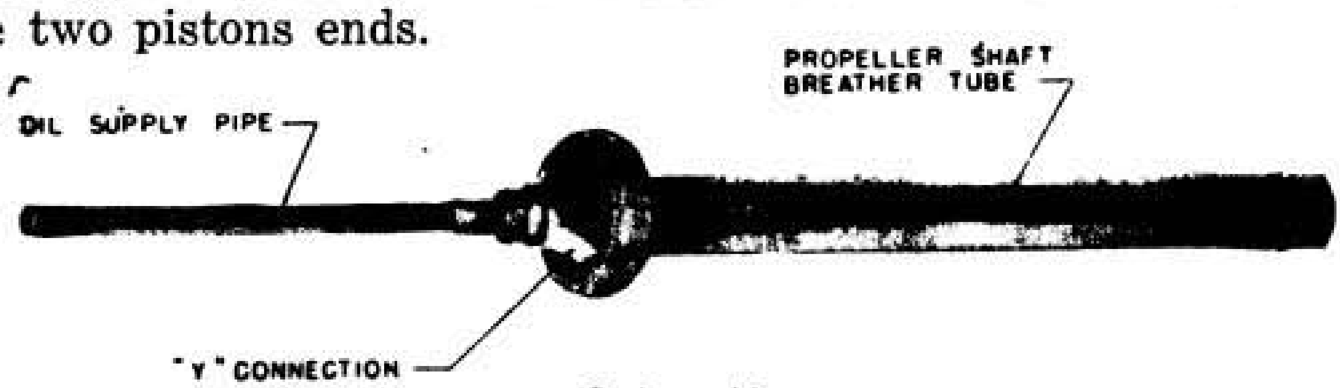


FIGURE 25.—Piston assemblies.

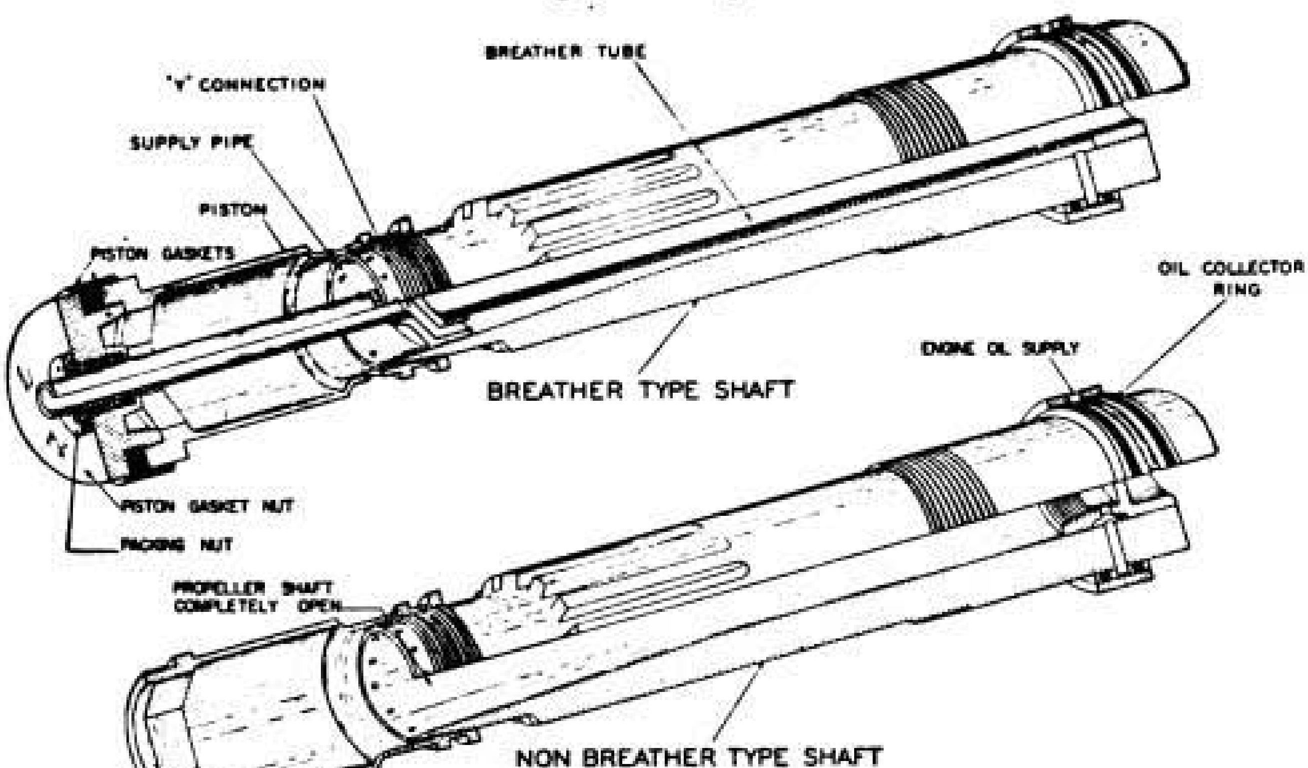
d. Piston of the propeller pitch-changing mechanism.—Two-position propellers may be installed on engines that have crankcase ventilation through the engine crankshaft and therefore

through the propeller shaft; or they may be installed on engines having other means of crankcase ventilation. A different type of propeller piston is used for each of the two installations.

(1) Each type of piston serves the dual purpose of acting as the retaining nut to hold the propeller on the propeller shaft and of acting as a guide for the cylinder. Each piston has a flange at the base end, over which the split front cone may be fitted. It is also threaded on the inside of the same end to fit the threaded end of the propeller shaft. At the outer end a shoulder is machined to carry the piston gaskets. The outboard piston gasket (fig. 25) forms an oiltight seal between the cylinder and the piston. The inboard gasket is a sleeve to permit the piston to guide the cylinder without metal-to-metal contact, and it also serves as an oil wiper. Different types of piston-gasket nuts thread to the outer end of each type of piston, and it is here that the resemblance between the two pistons ends.



① Assembly.



② Installations on breather and nonbreather types of shafts.
FIGURE 26.—Breather assembly and installations.

(2) A pipe line from the control valve on the nose of the engine directs oil under pressure to the propeller-shaft collector ring, which transfers the oil into the rotating propeller shaft (fig. 26②). On engines having crankcase ventilation through the propeller

shaft, some means is necessary to keep the engine oil separated from the engine-oil fumes, directing the oil through the piston into the cylinder and the fumes to the atmosphere. This is made possible by using a "Y" connection and the particular type of piston and piston gasket nut specifically designed for this purpose (fig. 25). The "Y" connection (fig. 26①), installed in the propeller shaft, carries the engine-oil fumes through a pipe in the center of the shaft. Engine oil flows around the outside of this pipe and inside the propeller shaft. When the oil and engine fumes reach the main part of the "Y" connection at the end of the propeller shaft, their positions relative to one another are changed. The oil is directed from the outside through small channels to a central hole. An oil supply pipe (fig. 26①) threads into this hole and carries the engine oil the length of the piston, from the "Y" connection to the piston gasket nut at the front of the piston. This nut is a disk with one small hole in the center. An oil-supply-pipe packing and nut prevent oil leakage between the oil supply pipe and the piston-gasket nut. In this manner the engine oil is directed into the cylinder (fig. 26②). There is no oil in the piston. On the other hand, the engine-oil fumes come directly through the central pipe to fill the area between the end of the propeller shaft and the piston-gasket nut, with the exception of the small channels and the oil supply pipe that carry the engine oil through the center. The fumes then escape through ventilating holes drilled in the base of the piston directly ahead of the threaded portion (fig. 25). The oil and fumes are thus kept separated and are directed to their proper destinations.

(3) This piston assembly used for propeller installation on an engine that has other means of crankcase ventilation differs in two respects from the piston assembly described: it does not have ventilating holes, and it has a "ring"-type piston-gasket nut (fig. 25). In this installation, engine oil fills the propeller shaft and piston, flowing directly into the cylinder (fig. 26②). The front cone for this installation has an extra groove to receive the front-cone packing washer (fig. 27). This washer prevents oil from leaking around the front cone, or past the piston and propeller shaft threads, down the spider and shaft splines, and out of the rear cone.

(4) Each type of piston is safetied with a piston lock ring and cotter pins. The lock ring fits over a hexagonal portion near the base of the piston, and is held to the spider by means of cotter pins. The cotter pins fit through holes in the lip of the lock ring and in the spider. One cotter pin is used for each blade, with the head toward the center of the propeller shaft.

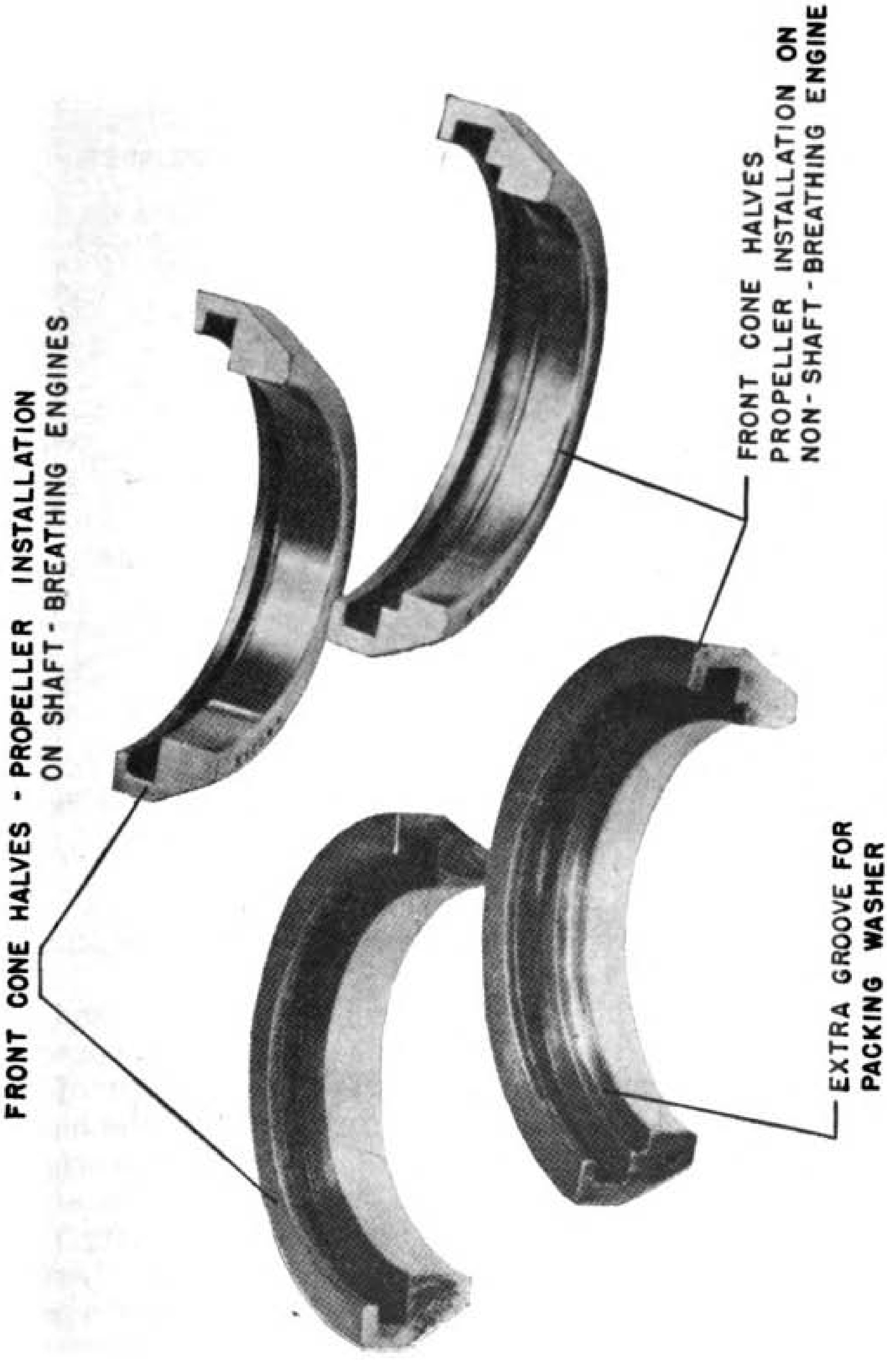


FIGURE 27.—Types of front cones.

e. Cylinder.—(1) The cylinder is machined from an aluminum-alloy forging. A steel liner is installed in the cylinder to prevent the piston gaskets from wearing its inner surface. The cylinder head threads into the outer end of the cylinder, and is safetied to the cylinder by means of a lock wire. A copper-and-asbestos cylin-

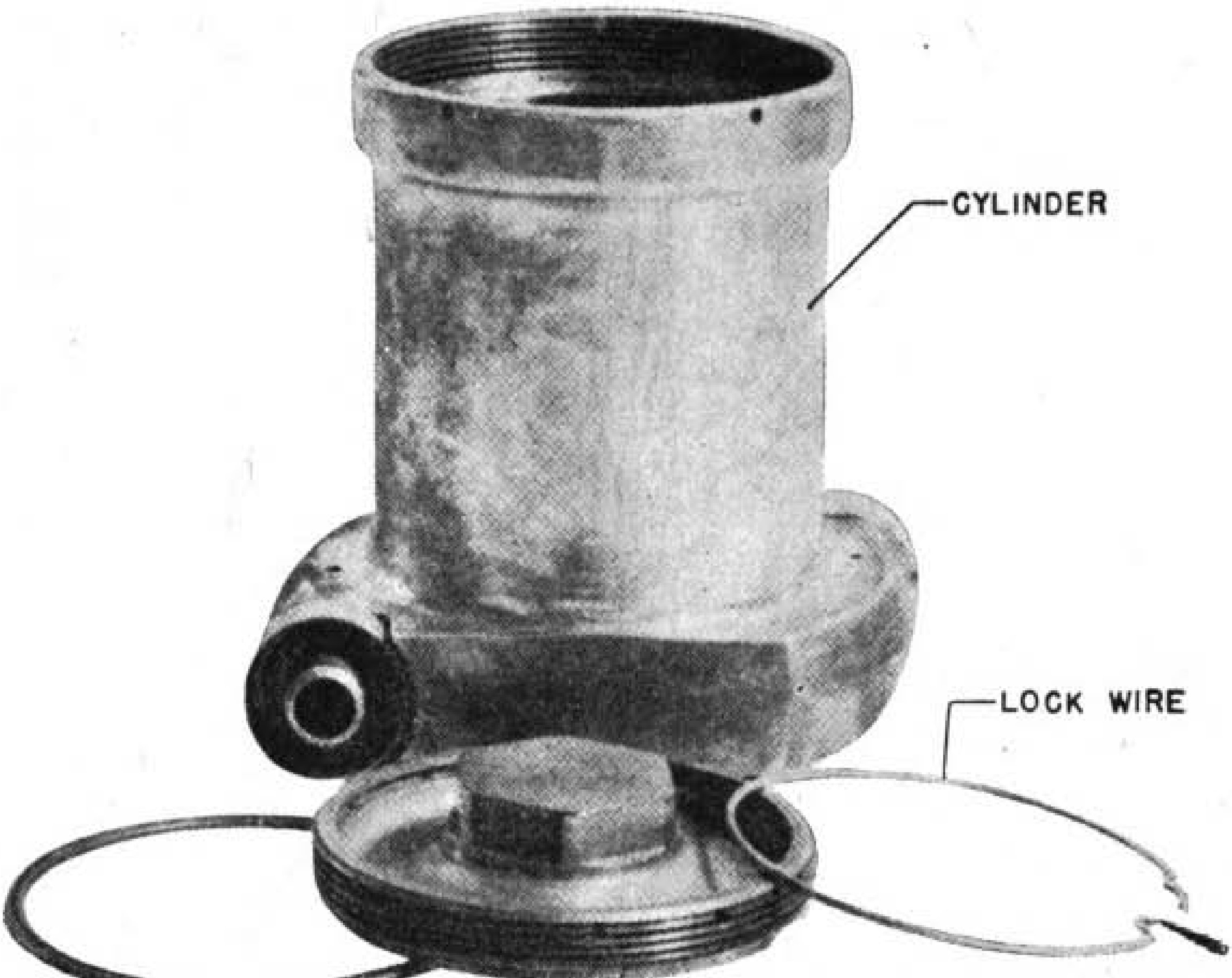


FIGURE 28.—Cylinder assembly.

der-head gasket provides an oil seal between the cylinder and the cylinder head (fig. 28).

(2) Engine oil flowing through the propeller shaft and the piston will act against the cylinder head to push the cylinder forward on the stationary piston. The forward linear motion of this cylinder must be translated into a rotating motion of the blades. Some means is necessary also to return the cylinder to its original position when the engine oil is drained out of the cylinder, and to return the blades to their original angle. These necessary functions are accomplished by the counterweight assemblies. Located in the flanged base of the cylinder are threaded holes, one opposite each spider arm. Into each of these holes is threaded the counterweight bearing shaft, part of the mechanical linkage of the counterweight assembly.

f. Counterweight assembly.—The counterweight assembly consists of the counterweight bracket, the counterweight bearing shaft, the counterweight, and the counterweight cap (fig. 29).

(1) The counterweight bracket is machined from a steel forg-

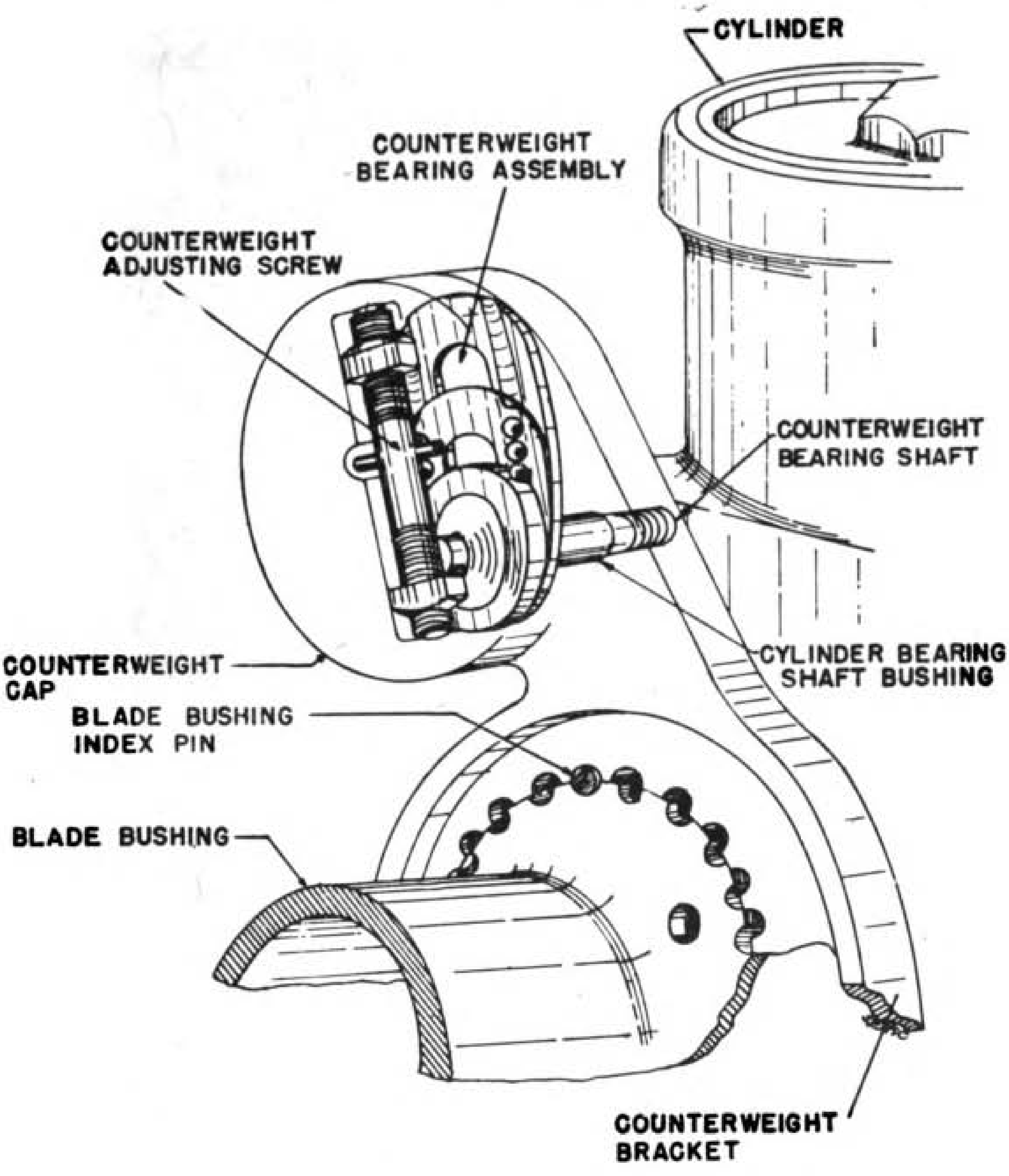


FIGURE 29.—Counterweight assembly.

ing. The inner, circular end fits around the blade bushing. The portion of the bracket next to the blade bushing, or its inner circumference, has 40 semicircular holes. The blade bushing itself has 36 semicircular holes around its base circumference. When the counterweight bracket is placed over the blade bushing, four semicircles on each will be matched to form circular holes 90° apart. Steel index pins, tapped into the four aligned sets of semicircles, insure that any turning movement of the bracket will cause the blade to rotate with it (fig. 30). The semicircles of the blade bushing and of the bracket are marked with numbers. These numbers

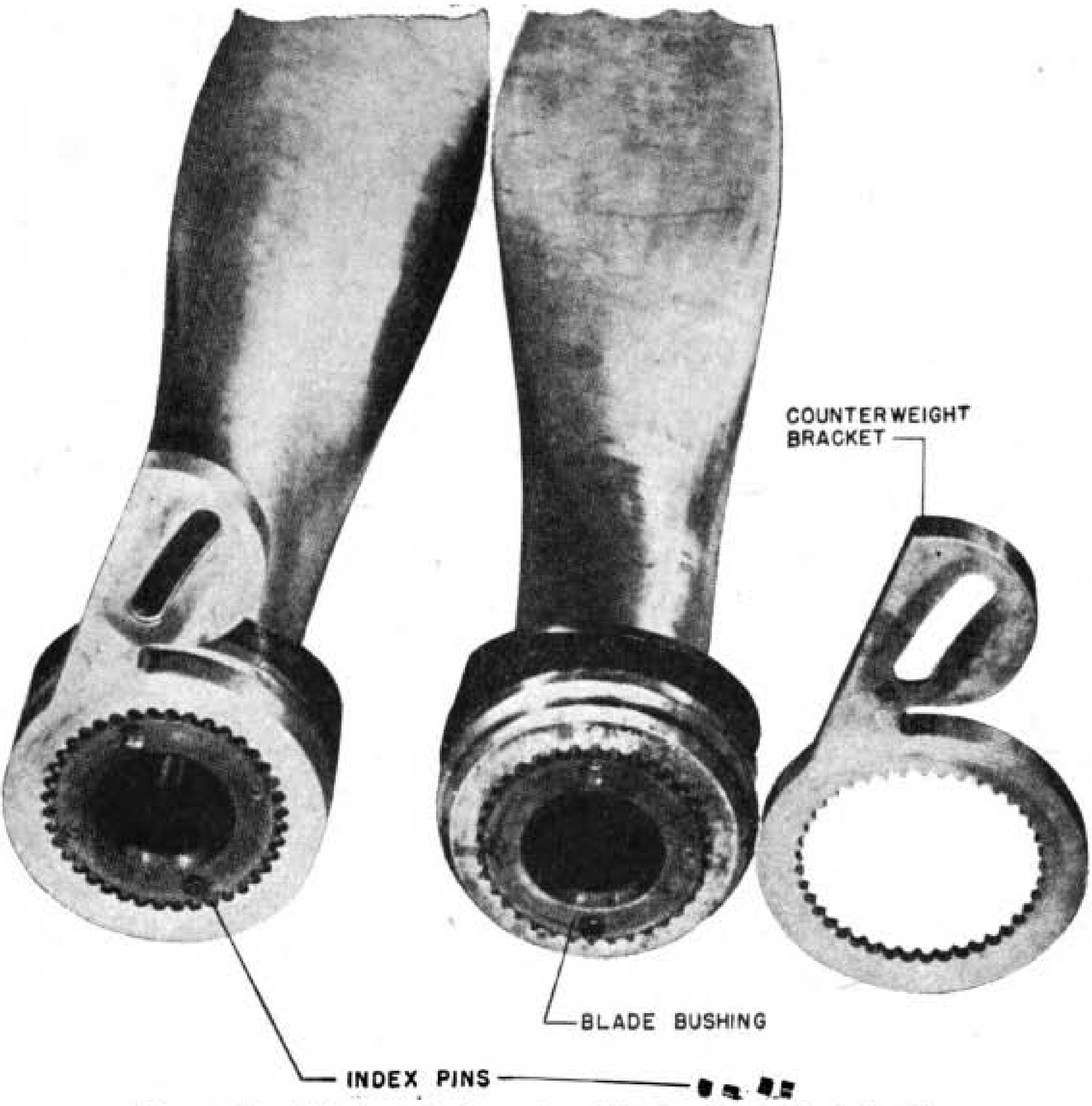


FIGURE 30.—Attachment of counterweight bracket to blade bushing.

mean "blade angle at the 42-inch station." The bracket is moved around on the butt of the blade until the desired numbers coincide, and index pins are inserted here and at the three other points where the holes coincide. The number at which the circular end of the counterweight bracket is matched with the blade bushing is the base or index setting. This setting is the highest pitch which the assembled propeller can obtain and is stamped on a lead plug in the counterweight. The other end, or "arm," of the counterweight bracket contains the cam slot, in which the counterweight bearing and shaft move.

(2) The counterweight bearing shaft is made of steel. One end is threaded to fit the holes in the flange at the base of the cylinder. The other end extends through the cam slot of the counterweight bracket, and has a cone which fits in the circular steel cap race of the counterweight bearing. The purpose of this bearing is to mini-

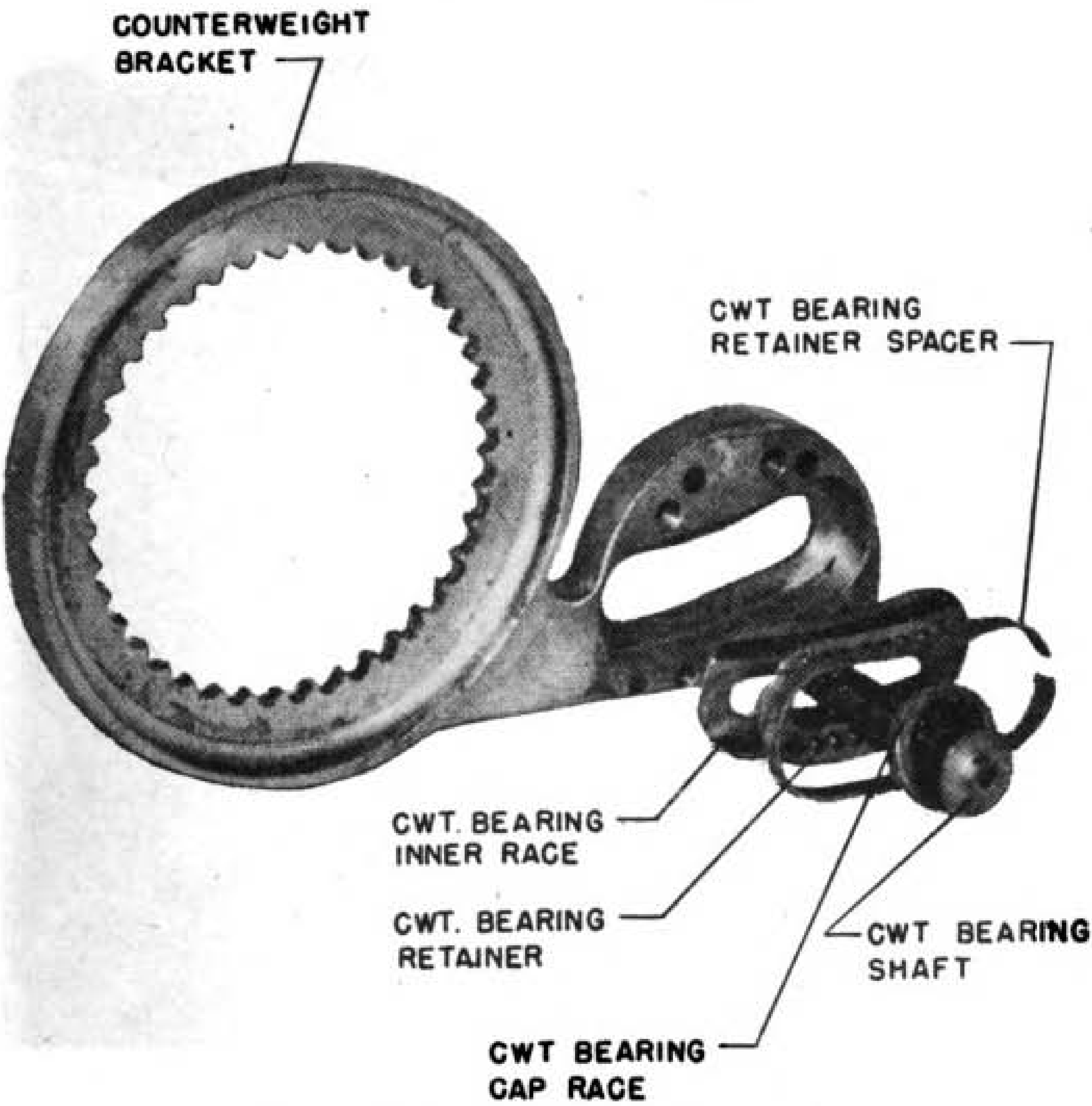


FIGURE 31.—Counterweight bearing assembly.

mize the friction of the bearing shaft's movement in the cam slot. The inner curved steel race of this bearing fits snugly in the cam slot of the counterweight bracket. A curved bearing retainer is held in place between the two races. A spacer, also included in the counterweight bearing assembly, serves as a guide for the retainer during pitch change (fig. 31). To provide rolling contact between the counterweight brackets and the cylinder, another bearing assembly, called the "counterweight bearing-shaft thrust bearing," is placed in each of the holes in the cylinder's flanged base (fig. 32). The counterweight bearing shaft has, besides the cone, a short extension at its outer end, the purpose of which is explained in the following paragraphs.

(3) A steel counterweight is fastened to the outer face of the bracket by means of screws. A slot in the counterweight corresponds to the cam slot in the bracket. As the engine oil acts against the cylinder head and pushes the cylinder forward, the counter-

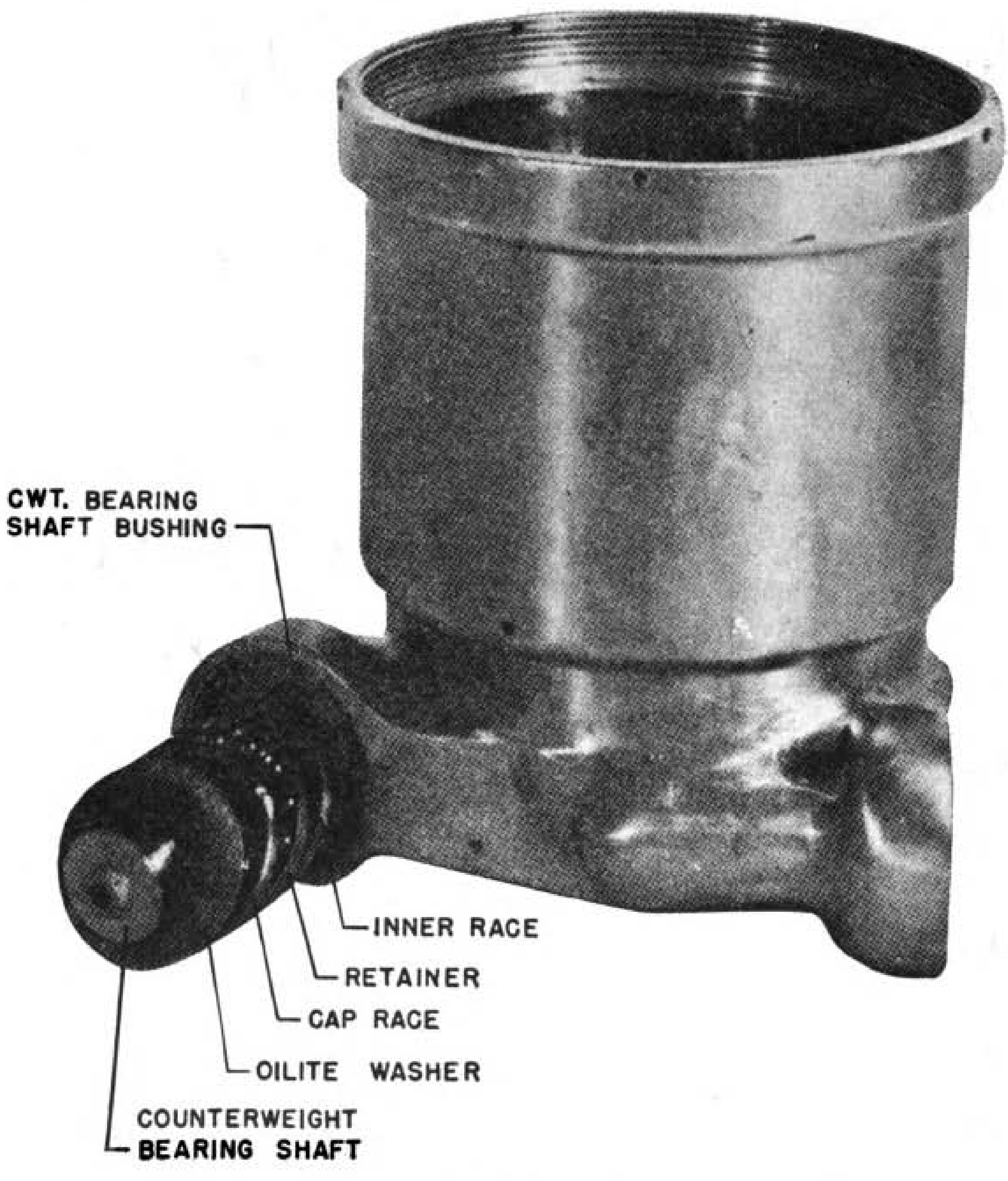
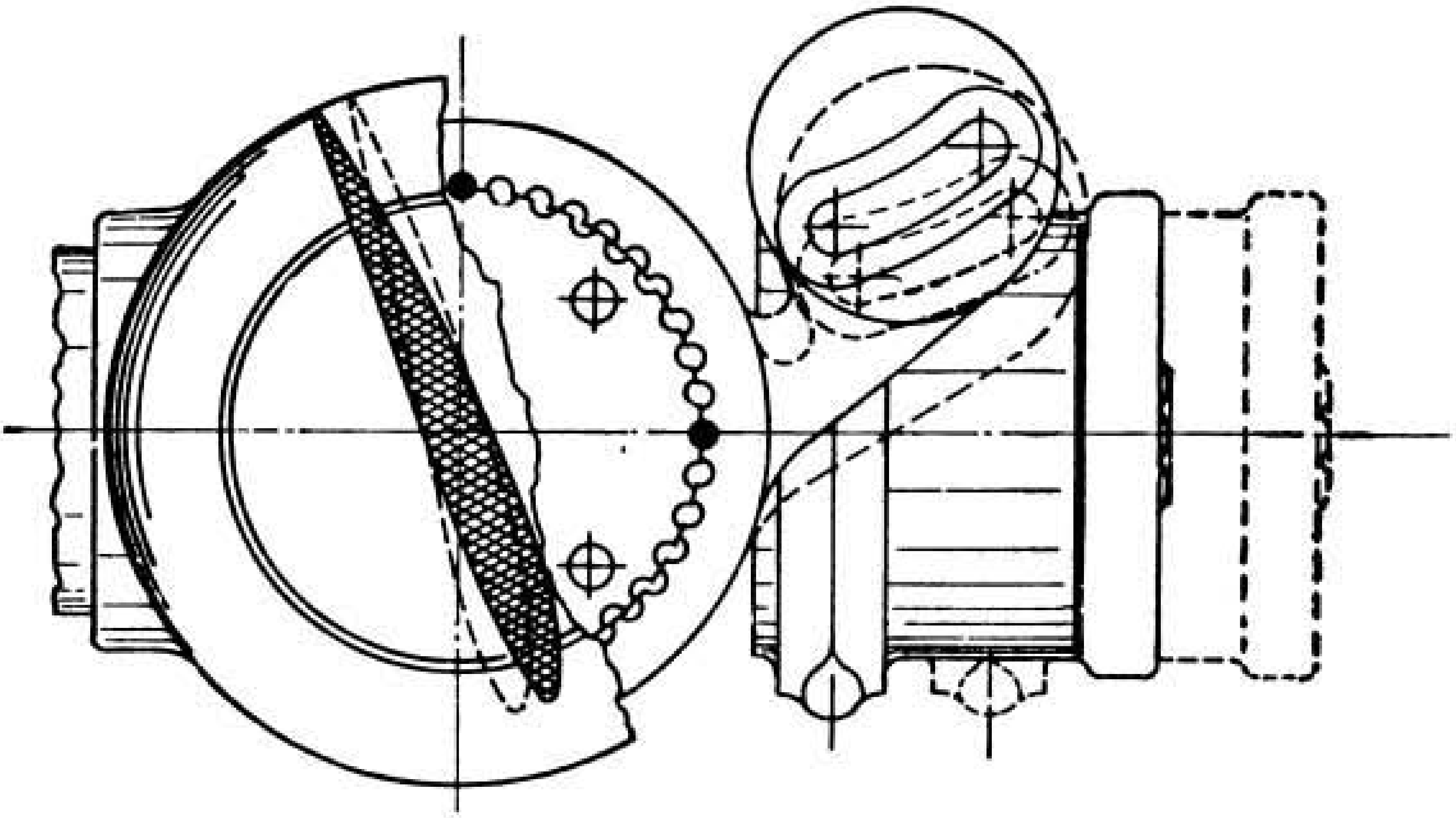


FIGURE 32.—Counterweight bearing-shaft thrust-bearing assembly.

weight bearing shafts move forward with the cylinder, to which they are threaded. The bearing shafts also move in the cam slots of the counterweight brackets, and move the bracket arms and counterweights closer to the axis of propeller rotation. This movement of the counterweight brackets rotates the blades to a low angle (fig. 33). When the engine oil is drained from the propeller cylinder, centrifugal force on the counterweights will throw them and the bracket arms away from the axis of rotation and put the blades into high pitch. In this case, the cylinder and bearing



LOW R.P.M POSITION SHOWN BY SOLID LINES
DOTTED LINES INDICATE HIGH R.P.M. POSITION
FIGURE 33.—Mechanical linkage of pitch-changing mechanism.

shafts will of course be forced to move in a rearward direction (fig. 33).

(4) An adjusting screw with a nut on each end fits into the slot in the counterweight that corresponds to the cam slot in the bracket. The screw is held from turning by a pin. The nuts may be turned up and down on this screw, independently of each other, to any desired position indicated by a scale stamped on one side of the counterweight slot. The short extension of the bearing shaft moves in the cam slot in the bracket and contacts the nuts on the adjusting screw. The travel of the cylinder, the movement of the counterweight bracket, and therefore the blade-angle range are limited by the extent of the movement of the bearing shaft as determined by the positions of the nuts (fig. 29).

(5) The scale along the side of the counterweight slot has degree graduations that run from 0 to 8, 0 to 10, or 0 to 15, depending upon whether the particular propeller has an 8°, 10°, or 15° maximum range. These graduations are stamped during final assembly and correspond with protractor measurements of the blade angle at the 42-inch station. Toward one end of the slot is a lead plug on which is stamped the base or index setting of the blade (see par. 18*f*(1)). To determine the blade-angle range, the numbers on the scale opposite the two nuts are subtracted separately from the index setting. For example, suppose the adjusting nuts on a 10° propeller are set at 0 and 10, and the index setting stamped on

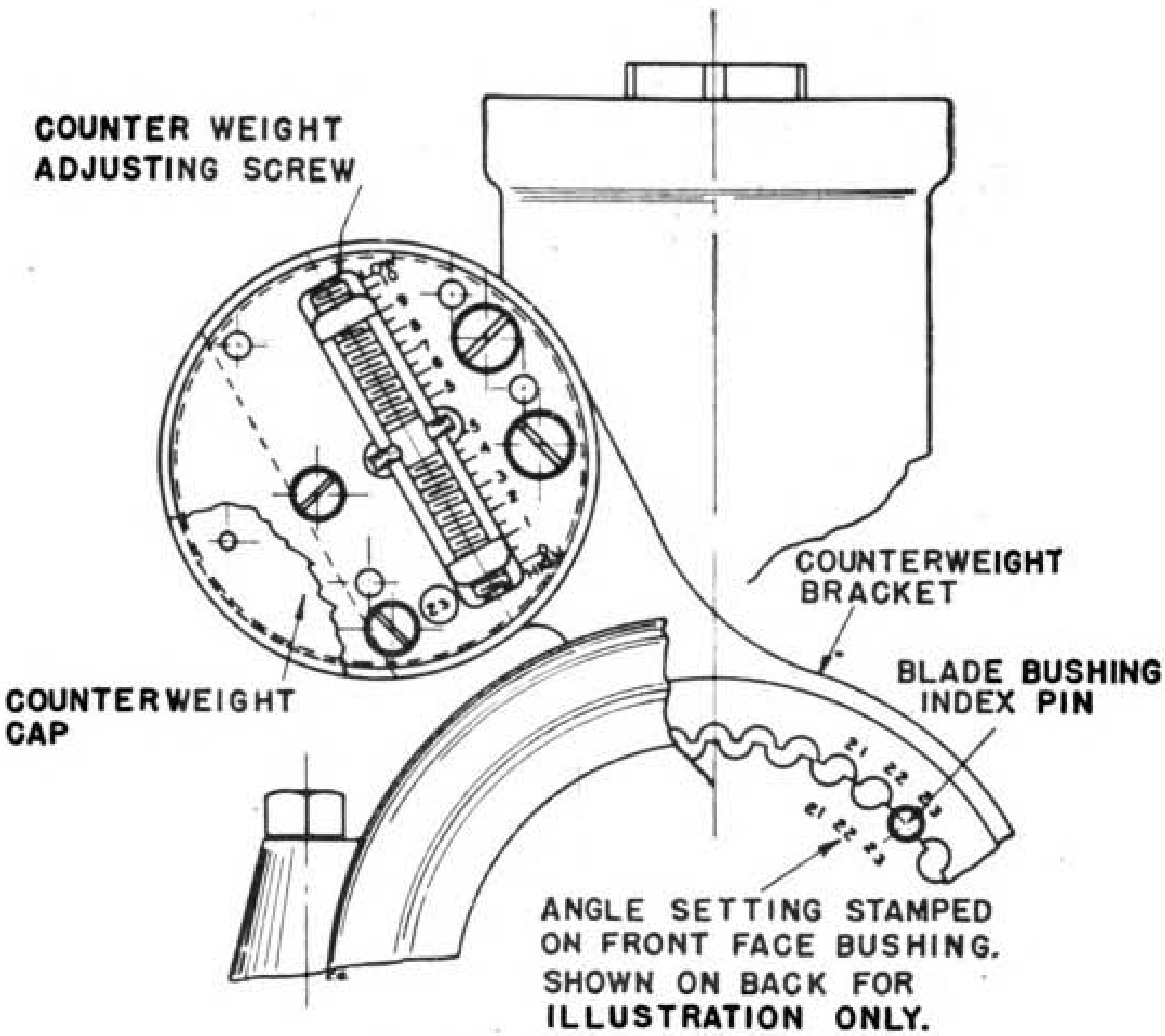


FIGURE 34.—Blade-angle adjustment.

the lead plug is 23 (fig. 34). The high angle will be 23 — 0, or 23°, and the low angle will be 23 — 10, or 13°. This means that when engine oil fully extends the cylinder so that the bearing shaft strikes the adjusting nut farthest from the hub, the blades will be at a 13° low angle. This nut is opposite 10 on the scale. On the other hand, when centrifugal force on the counterweights move the cylinder back until the bearing shaft strikes the inner adjusting nut opposite 0 on the scale, the blades will be at a 23° high angle. A propeller so adjusted has the highest blade angle, lowest blade angle, and the greatest blade-angle range—10°—that is possible with the propeller indexed at 23°. Either adjusting nut may be turned toward the center to change the high or low angle and the blade-angle range. For example, the outer adjusting nut may be turned to 9, giving a low angle of 14°; or to 8, giving a low angle of 15° (fig. 34). The inner nut may be turned to 1, giving

a high angle of 22°; or to 3, giving a 20° high angle; and so forth. These adjustments make possible different high- and low-blade angles, and different blade-angle ranges, so that the propeller may be set for installation on different engines and airplanes.

(6) A counterweight cap screws on the face of the counterweight to complete the counterweight assembly. It acts both as a protecting cover for the adjusting screw and nuts and as an added weight to help pull the blades into the high-pitch position.

19. Principle of operation.—The flow of oil for operating the pitch-changing mechanism is controlled by a manually operated valve. This is mounted on the nose of the engine, and is connected by cables or push-pull rods to the control in the cockpit. It is called a three-way valve because it has three ports; however, it has only two positions. In one position the valve connects the pressure-line port from the engine with the propeller-line port. Oil flows to the collector ring on the propeller shaft, into the rear end of the shaft, and then out to the propeller cylinder. Engine oil pressure forces the cylinder to move forward; the counterweight bearing shafts are pulled forward in the cam slots of the counterweight brackets, which are attached to the blade butts. The movement thus imparted to the brackets by the bearing shafts results in rotary motion of the blades to low pitch. The centrifugal twisting movement of the blades also aids in decreasing the blade angle. When the three-way valve is turned to the other position, it aligns the propeller-line port with the drain-line port. The flow of oil from the engine is shut off, and the oil in the propeller cylinder drains back to the engine sump. Centrifugal force on the counterweights, unopposed by engine oil pressure, causes the counterweights to fly outward. The resulting movement of the counterweight brackets turns the blades to high pitch. The blades of this propeller cannot be stopped at an angle between the high- and low-pitch settings; the blades must be in either full-high or full-low pitch.

20. Preflight operation.—*a.* The following operations check of the propeller controls is made before the first flight of the day:

(1) Prior to starting the engine, the propeller control will be placed in the high-pitch (low rpm) position. After the engine is started, it is run for at least 1 minute with the control in this position. This is necessary in order to avoid possible lack of oil to the master rod bearings of the engine, as engine oil is required to hold the blades in the low-pitch position.

(2) After approximately 1 minute, the propeller control is shifted to the low-pitch (high rpm) position, causing the propeller to shift to low pitch. The warm-up must be at the required rpm

and to the proper temperature as specified in the operating instructions for the particular type of engine.

(3) When the engine has been warmed-up to the specified operating temperature, leave the propeller control in the low-pitch (high rpm) position and set the throttle to give approximately 1,400 rpm except where limitations have been listed on specific engines.

(4) Shift the propeller control into the high-pitch (low rpm) position and note the decrease in engine rpm on the tachometer. This decrease in engine rpm indicates that the propeller is functioning correctly, the amount of change depending upon the range of the propeller.

(5) Without changing the position of the throttle, move the propeller control to the low-pitch (high rpm) position and note the increase in engine rpm. This change signifies that the propeller is going into the low-pitch position.

(6) As a further check, it is good practice to have an observer stationed outside the airplane at a point where the movements of the cylinder can be observed. He may signal the rearward and forward movements of the cylinder.

b. Before the engine is stopped, the propeller control is placed in the high-pitch position. This is done so that the cylinder will move to its most rearward position, covering most of the piston. In this position, the cylinder prevents exposure and corrosion of the propeller piston on an idle engine. Also, most of the oil leaves the piston and cylinder, so that congealing of a considerable amount of the engine oil in cold weather will not occur. With "stiff" oil in the proper cylinder, it would be difficult to adjust the pitch-changing mechanism to a higher pitch.

21. **Removal and installation.**—*a*. *Removal.*—The method of removing the Hamilton standard two-position propeller from the propeller shaft is as follows:

(1) Check to see that the blades are in the high-pitch position. If not, use a blade beam on each blade, and move all blades at the same time. Never use a hammer or mallet on blades, cylinder head, or counterweights when changing the position of the blades. In the high-pitch position the cylinder is not full of oil, and the piston-gasket nut is in a position to be removed.

(2) Remove the cylinder-head lock wire and unscrew the cylinder head. Remove the cylinder-head gasket. Have a pail handy to catch the oil that remains in the cylinder.

(3) *If the engine has crankcase ventilation through the propeller shaft,* unsafety and remove the oil-supply-pipe packing nut; then

unsafety and remove the piston-gasket nut. The oil supply pipe has a slot in its end, and the packing nut is safetied to it with safety wire. If the piston-gasket nut were removed before the oil-supply-pipe packing nut, which threads into it, serious damage to the oil supply pipe would result. *If the engine has other means of crankcase ventilation,* unsafety and remove the piston-gasket nut.

(4) Remove the two piston gaskets.

(5) Using blade beams, put the propeller in the low-pitch position.

(6) Remove the cotter pins from the piston lock ring, and slide the ring up on the piston.

(7) Having unsafetied the piston, put the propeller back into the high-pitch position.

(8) Unscrew the piston. This will start the propeller off the propeller shaft.

(9) Using a hoist and slings, slide the propeller slowly forward and remove it from the propeller shaft. A thread protector should be used to prevent damage to the propeller shaft threads. Care should also be taken not to hit the oil supply pipe, if one is installed in the end of the shaft.

(10) Remove the rear cone and the rear-cone spacer (if used) from the propeller shaft.

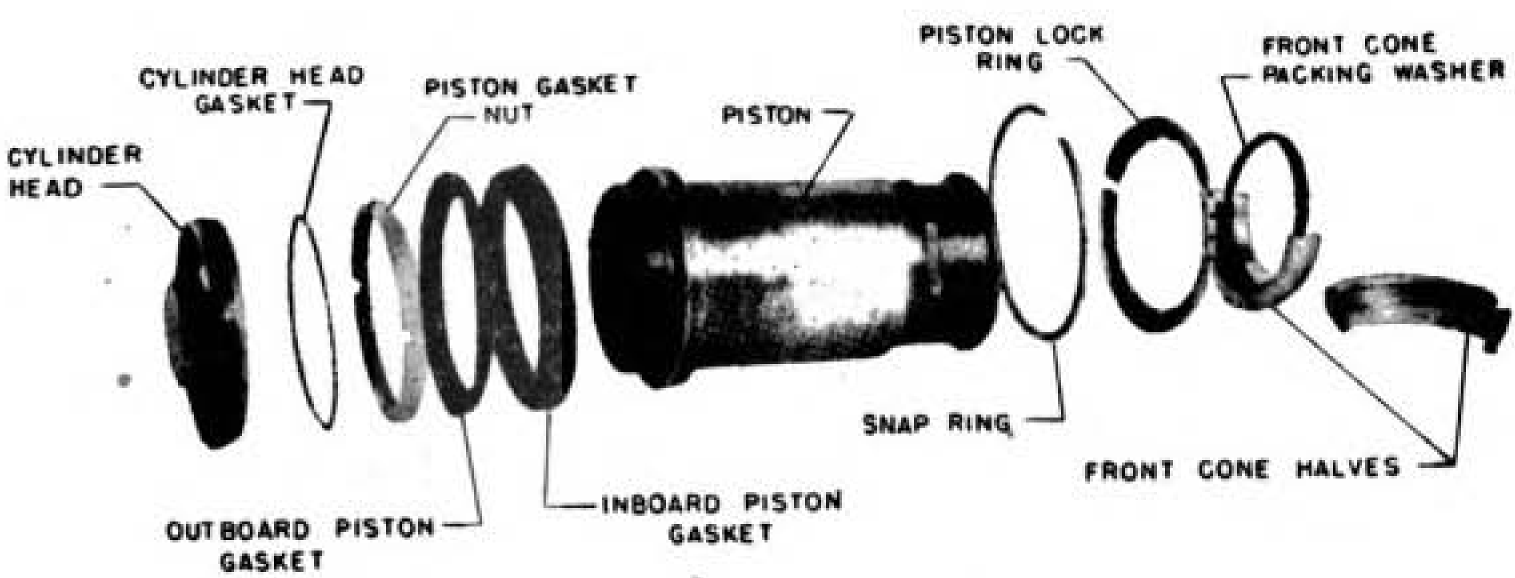


FIGURE 35.—Propeller attaching parts.

(11) If the piston is to be removed, the propeller must be put in the low-pitch position. This is necessary to provide an open space at the base of the cylinder. Through this space the snap ring may be removed from its groove in the spider. The piston is then moved forward through the cylinder, after which the front cone,

snap ring, and piston lock ring may be removed through the space at the base of the cylinder, and the piston may be removed from the cylinder (fig. 35).

b. Installation.—The proper procedure for installing a Hamilton standard two-position propeller is as follows:

(1) Thoroughly clean out the inside of the front portion of the propeller shaft. Remove the screw plug, if any, from inside the propeller shaft.

(2) If the engine has crankcase ventilation through the propeller shaft, screw the oil supply pipe into the Y connection, taking care not to tighten it too much, and safety. If the oil supply pipe is already installed, check the installation. On this type of installation, the piston and attaching parts must be installed in the propeller before the propeller is placed on the shaft. This is necessary because the oil supply pipe prevents the insertion of the snap ring and the lock ring at the base of the cylinder when the propeller is on the shaft.

(3) Having made sure that the splines and propeller parts are free from defects, oil the splines of the propeller shaft and hub, the front cone and front-cone seat. The rear cone and rear-cone seat will be left dry.

(4) Install the rear cone.

(5) Align the wide groove of the hub with the wide spline on the propeller shaft, and slide the propeller on the shaft. Care must be taken to avoid damaging the oil supply pipe, if used. A thread protector should be used to prevent damage to the shaft threads.

(6) In the case of engines not having crankcase ventilation through the propeller shaft, if the piston is not already installed, the propeller must be put in the low-pitch position. Great care must be taken, not only to move all the blades at the same time, but also not to pull the propeller off the shaft when the piston is not holding it securely to the shaft. Coat the threads of the piston with thread lubricant as specified in Technical Orders. Insert the piston through the cylinder, and assemble the piston lock ring, snap ring, and front cone of the piston through the opening at the base of the cylinder.

(7) Carefully start the piston on the propeller shaft by hand. If the cylinder is correctly aligned and the piston or shaft threads are not damaged, the piston will screw on easily. In no case should force be used to tighten the piston if there is binding or indication that the threads are not properly started. Care is taken in tightening the piston to see that the front-cone packing washer, when one is required, does not bind but is pulled properly into place.

The piston should be tightened a few turns and then the hub jarred slightly by hand. When the piston is correctly started as far as it will go by hand, put the propeller in the high-pitch position. This will help to prevent jamming of the washer on the shaft threads.

(8) For final tightening of the piston, a force of approximately 175 pounds should be applied at the end of a 4-foot bar. To insure the piston being pulled home, the bar should be rapped once on the section next to the wrench, using a normal swing and not more than a 2½-pound hammer. Do not in any case attempt to tighten the piston by hammering on the end of the bar.

(9) Put the propeller in the low-pitch position.

(10) Install the snap ring in the groove in the spider. Then secure the piston with the lock ring, and safety the lock ring to the spider with a cotter pin for each blade. The heads of the cotter pins should be toward the center of the shaft.

(11) Put the propeller in high pitch.

(12) Install the inboard and outboard piston gaskets over the forward end of the piston.

(13) Install the piston-gasket nut. If the engine has crankcase ventilation through the propeller shaft, be sure that the oil supply pipe enters the hole in the center of the piston-gasket nut for this type of installation. Using the special wrench and a 1½-foot bar, tighten the nut to an oil seal, and safety.

(14) If the propeller has crankcase ventilation through the propeller shaft, install the oil-supply-pipe packing and packing nut, tighten the nut, and secure it to the supply pipe with safety wire.

(15) Place the cylinder-head gasket on the cylinder head, with the asbestos toward the cylinder head. A light coating of grease may be used to hold this gasket in place.

(16) Screw the cylinder head onto the cylinder. The special wrench and a 1½-foot bar should be used to tighten the cylinder head to an oil seal.

(17) Lock the cylinder head to the cylinder by means of the cylinder-head lock wire.

(18) A check of all lock wires and cotter pins completes the installation of the propeller.

22. Inspection and maintenance.—Reference should be made to section XI for general maintenance and repair. Specific inspection and maintenance performed on the two-position propeller are covered in the paragraphs that immediately follow.

a. Oil and grease leaks.—After the daily or preflight warm-up,

the propeller is inspected for oil and grease leaks. Any leaks must be corrected before flight. The most probable leaks, their cause and correction, are as follows:

(1) Oil leaking around the cylinder head may be due to a loose cylinder head or a damaged cylinder-head gasket. The cylinder head should be tightened or the gasket replaced.

(2) Oil leaking at the base of the cylinder may mean that the outboard piston gasket is defective, or the gasket nut may be loose. Replace the gasket or tighten the nut.

(3) If the engine has crankcase ventilation through the propeller shaft, oil may be leaking out of the ventilating holes in the piston. The oil-supply-pipe packing may be damaged, or the nut loose. Oil also may be leaking at the other end of the supply pipe where it threads into the Y connection. Tighten loose nut or pipe; replace damaged seals.

(4) If the engine has other means of crankcase ventilation, oil may be leaking from around the front cone or at the rear of the barrel. If so, the front-cone packing washer is defective and must be replaced.

(5) If grease is found on the blade shanks, check to make certain that it is not surplus grease forced into the barrel halves during lubrication of the spider. If it is not surplus grease, a spring-loaded grease retainer is damaged or incorrectly installed. It is necessary to disassemble the propeller to replace a grease retainer; the propeller must therefore be removed from the shaft.

b. Safetying devices.—The visible safetying devices of the propeller should be checked at periodic inspections. These safeties are:

(1) The cylinder head lock wire.

(2) For the piston: the piston lock ring and cotter pins.

(3) For the counterweight bearing shafts: clevis pins and cotter pins.

(4) For the counterweight caps: clevis pins and cotter pins.

(5) For the barrel-bolt nuts: cotter pins.

c. Piston looseness.—The piston should be checked for looseness in the following manner:

(1) With the aid of blade beams, move the propeller into full high pitch.

(2) Remove the cylinder-head lock wire, the cylinder head, and the cylinder-head gasket.

(3) Unsafety and remove the oil-supply-pipe packing nut (if used), and then remove the piston-gasket nut and piston gaskets.

(4) Put the propeller in low pitch, and unsafety the piston by

removing the cotter pins from the piston lock ring. Pull the lock ring forward on the piston.

(5) Put the propeller in high pitch. Insert the special wrench into the piston. A force of 175 pounds should be exerted on the end of a 4-foot bar. A steady pull on the end of the bar without jerking is recommended for the check.

(6) Put the propeller in low pitch and resafety the piston.

(7) Put the propeller in high pitch. Replace the piston gaskets, the gasket nut, and the oil-supply-pipe packing and nut (if used).

(8) Replace the cylinder head and gasket, and safety the cylinder head with its lock wire.

d. Cleaning the piston.—To clean and lubricate the exposed portion of the piston, put the propeller into the full low-pitch position, using blade beams. For cleaning use kerosene, gasoline, or some approved cleaning fluid, according to instructions in Technical Orders. Inspect the piston for wear, galling, corrosion, etc.; carefully remove any defect, using fine sandpaper or crocus cloth. Coat the surface of the piston with clean engine oil. Return the propeller to the high-pitch position.

e. Propeller control.—The propeller control in the cockpit is checked for security of mounting and freedom of movement. All bell cranks, rods, tubes, and cables are inspected for defects and corrosion. Determine by movement of the cockpit control that the operating arm of the three-way valve has full range of movement. Coat all controls with clean engine oil.

f. Cylinder running eccentrically.—During warm-up of the engine, it may be found that the cylinder runs eccentrically when in the low-pitch or fully extended position. This is usually due to the fact that the extensions of the counterweight bearing shafts are not striking the upper adjusting nuts simultaneously. To correct this condition, first stop the engine in the full low-pitch position. Remove the counterweight caps and check to see if each counterweight bearing-shaft extension is striking its upper adjusting nut. This may be determined by ascertaining whether the adjusting screws are held tightly. If one or more adjusting screws are found loose, make corrections by adjusting the nuts until they all bear against the bearing-shaft extensions at the same time. If any adjustment is made, the blade angles must be checked.

g. Counterweight bearing and shaft.—The counterweight bearing-and-shaft assembly should be checked for looseness. The proper clearance of 0.002 to 0.003 inch will be maintained by the addition of shims of the required thickness. Care should be taken

not to disturb the setting of the adjusting nuts when adding the shims.

h. Lubrication of the hub spider.—At the periodic inspection specified in Technical Orders, the hub spider is filled with grease. It is also lubricated before the propeller assembly is installed on the engine or is placed in storage. To lubricate the hub spider, fill a Zerk gun with the proper grease as specified in Technical Orders. The power-type Zerk gun should be adjusted to cut out at a pressure of 2,000 pounds per square inch. To keep trapped air from preventing the proper amount of lubricant entering the spider arms, lubrication should be performed as follows:

(1) Apply the gun to a grease fitting on the spider through a hole in the barrel halves. Force about one-third of the amount of grease necessary to fill it into the spider arm.

(2) Remove the gun and proceed to the next grease fitting, forcing in a similar amount of lubricant.

(3) Repeat the operation until the spider arms are full of lubricant. This will be indicated, when a hand-type Zerk gun is being used, by a sudden increase in the force required to operate the handle. The power-type Zerk gun will kick out at the pressure for which it was set. Any continuation of greasing beyond this point does no particular good and is undesirable.

(4) It will be found that a lapse of time between the partial filling of each spider arm permits the trapped air to escape, thus providing space for additional grease to enter the socket.

(5) If grease appears on the shank of a blade, check to make certain that it is not surplus grease which has been forced around the fittings and into the barrel halves during lubrication. If this is not the case, the spring-loaded leather grease retainer is probably defective and is permitting grease from the spider arm to leak out between the barrel and the blade. A defective retainer must be removed and replaced.

i. Lubrication of the counterweight bearing assembly.—The principal purpose of lubricating the counterweight bearing assembly is to provide a protective film of grease to prevent corrosion. Lubrication of moving parts is a secondary purpose. These bearing assemblies can be lubricated through the slot in the counterweight without removing the cap. The proper grease as specified in Technical Orders is hand-packed into the counterweight slot. If the counterweight cap is removed, extreme care must be exercised to insure that the location of the stop nuts on the adjusting screws is not disturbed, as any change in the position of these nuts will result in a change of the blade angle.

23. **Service use.**—Hamilton standard two-position propellers are used almost entirely on basic trainers. However, the three-way valve control unit is often replaced by a constant-speed governor, so that the propeller actually becomes a constant-speed propeller. Many constant-speed installations of this type are to be found in service use—on cargo ships, observation airplanes, and advanced trainers as well as on basic trainers. To understand the constant-speed operation of this propeller, section V should be studied carefully.

Section V

HAMILTON STANDARD CONSTANT-SPEED PROPELLERS

24. **General.**—As indicated in section I, a constant-speed propeller maintains the airplane engine at a constant speed by automatically changing the blade angle to compensate for changes in flight conditions. Increased engine efficiency, less engine wear, less fuel consumption, increased blade efficiency, and improved flight characteristics result from constant-speed operation. An engine using a constant-speed propeller develops maximum rated horsepower during take-off and climb because the blades can be rotated to an angle low enough to permit the engine to turn at its maximum rated rpm. Also the blades can be rotated to an angle high enough to prevent engine overspeeding in level flight and in a dive, and to prevent braking action in a dive. The desired propeller thrust for different power-output and airplane-attitude combinations is thus provided. Because of the additional available power, the airplane will respond more rapidly and certainly to manipulation of the controls, and more difficult maneuvers will be possible.

25. **Description.**—Hamilton standard constant-speed propellers utilize the same hydraulic principle of operation as the Hamilton standard two-position propellers (see section IV and fig. 36). How-

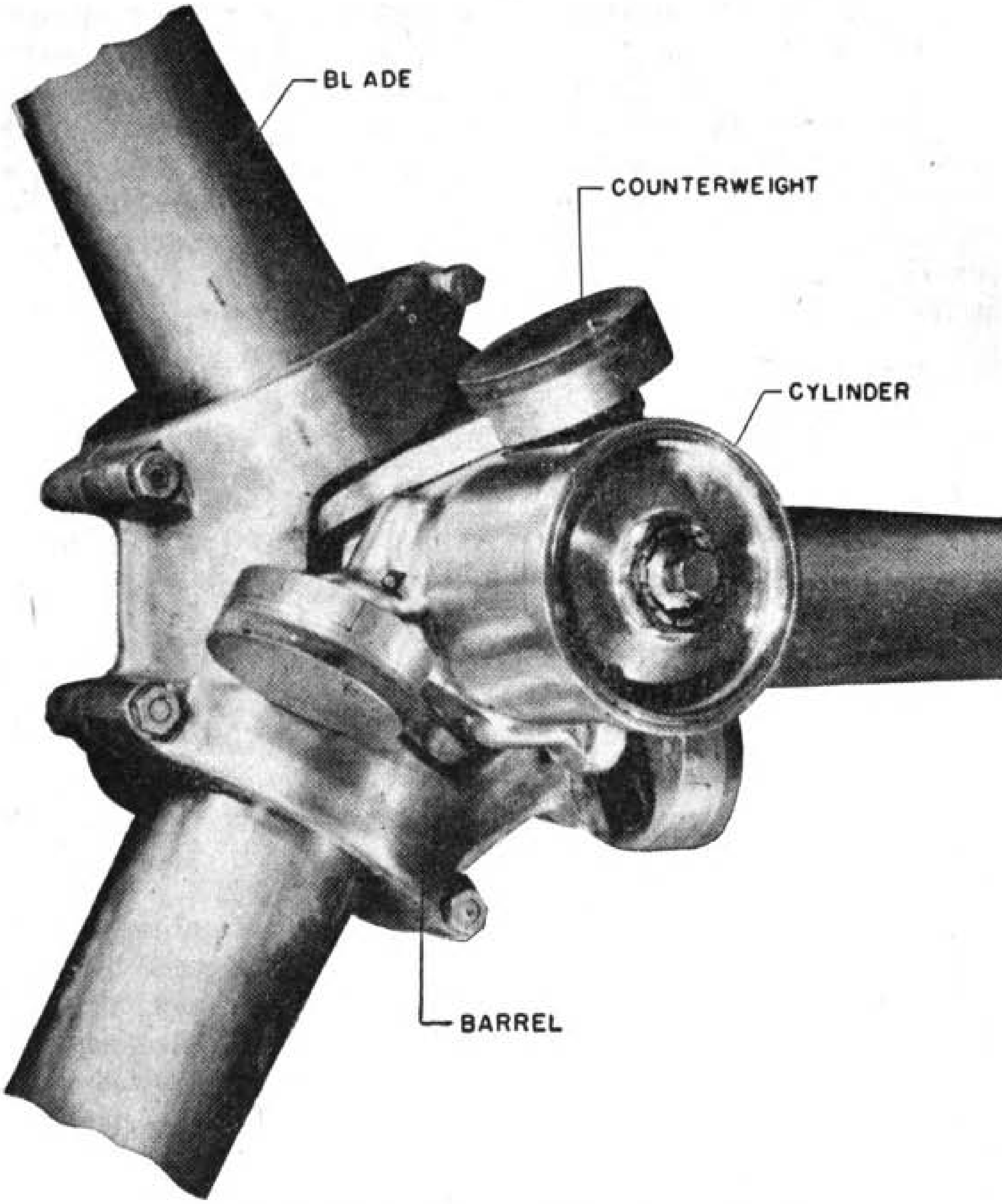


FIGURE 36.—Hamilton standard constant-speed propeller.

ever, to provide constant-speed operation, a constant-speed propeller governor replaces the three-way valve. The two types of propellers are essentially alike in construction; the spider, barrel halves, and blades are almost identical (see sec. IV). The main differences in construction are in the piston and cylinder.

a. Piston assembly.—Only one type of piston is used to hold the constant-speed propeller or the propeller shaft. This piston is used on engines that have crankcase ventilation through the propeller shaft and on engines that have other means of crankcase ventila-

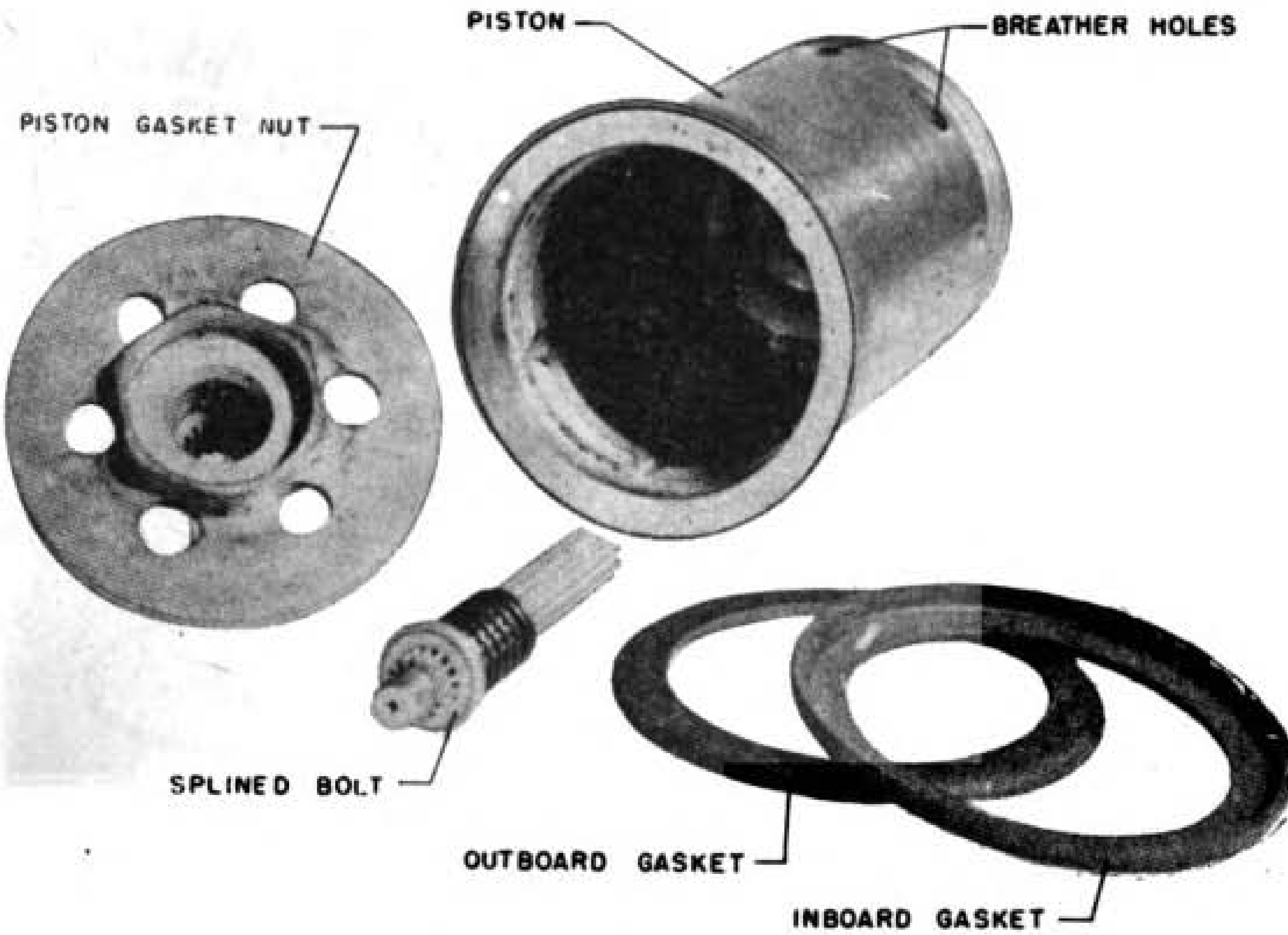


FIGURE 37.—Piston assembly.

tion. This piston has a flange at its base over which the split front cone fits. It is also threaded on the inside of the same end to fit the threaded end of the propeller shaft. At its outer end, a shoulder is machined to carry the piston gaskets. A piston-gasket nut threads into the outer end of the piston to hold the gaskets in place. This is a disk type nut with holes to permit the oil that operates the pitch-changing mechanism to flow into the cylinder (fig. 37).

(1) To permit the oil fumes of engines having crankcase ventilation through the propeller shaft to escape into the air, several holes are drilled in the base of the piston directly ahead of the threaded portion. The piston also has a "false bottom" directly ahead of the ventilating holes. In the center of this false bottom is a small-diameter hole with a self-sealing oil seal (see fig. 38①). If the constant-speed propeller is installed on an engine that has crankcase ventilation through the propeller shaft, a Y connection is installed in the propeller shaft. A short oil supply pipe threads into the forward end of the Y connection and carries the governor oil through the false bottom of the piston. The oil thus fills the piston and flows into the cylinder. The engine-oil fumes fill the area of the piston between the end of the propeller shaft and the false bottom, with the exception of the small channels and the oil

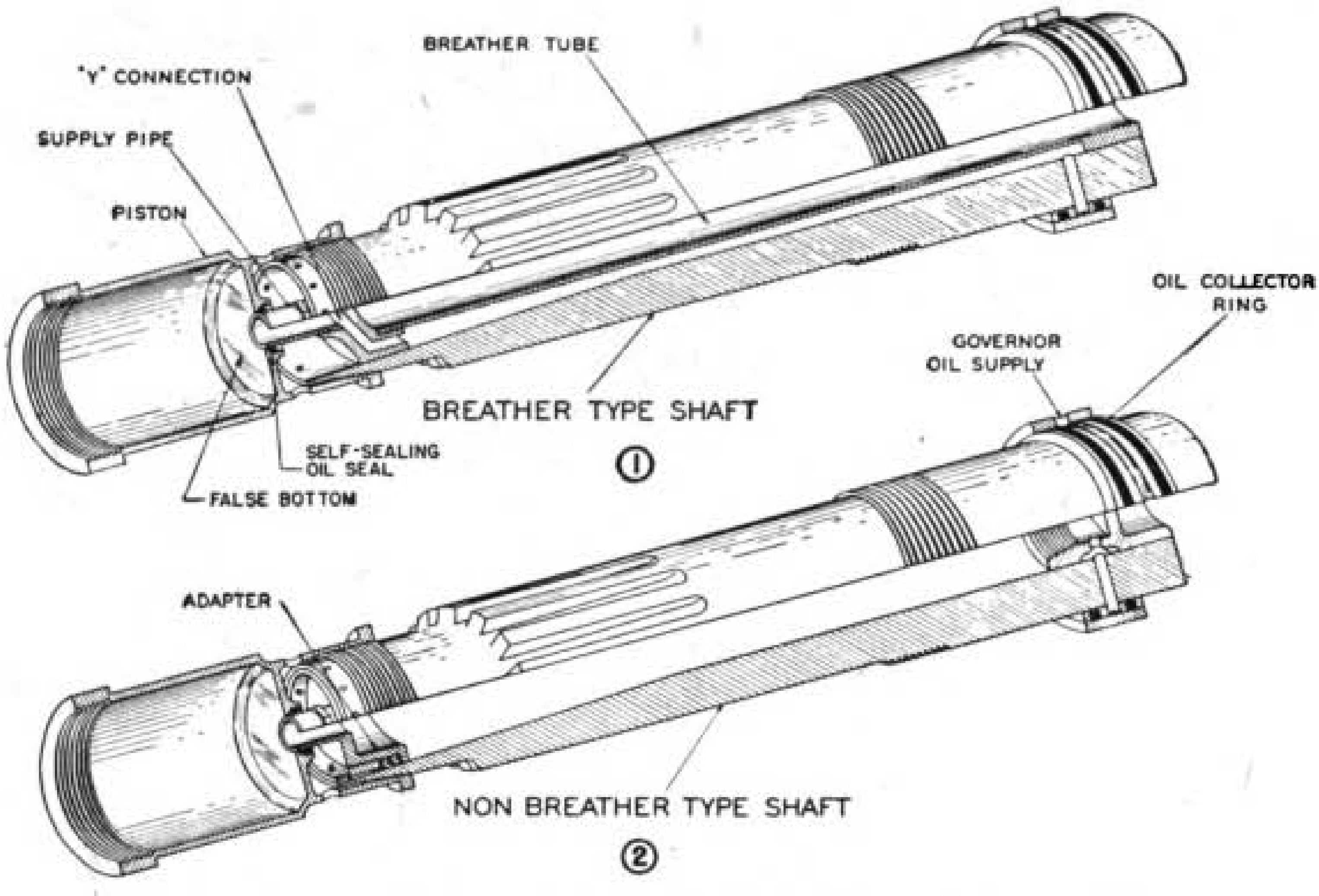


FIGURE 38.—Installations on breather and nonbreather types of shafts.

supply pipe that carry the governor oil through the center. The fumes then escape through the ventilating holes in the piston (fig. 38①).

(2) If the constant-speed propeller is installed on an engine that has other means of crankcase ventilation than through the propeller shaft, an adapter is installed in the propeller shaft. This adapter, with chevron oil seals around its outside circumference, plugs the end of the shaft and is secured by four screws, which are inserted through the locking holes of the propeller shaft. The short oil supply pipe of the adapter carries the governor oil from the propeller shaft through the false bottom of the piston. The governor oil thus bypasses the ventilating holes in the piston in this particular type of installation (fig. 38②).

b. Cylinder assembly.—The cylinder assembly of the constant-speed propeller is similar in most respects to that of the two-position propeller. However, the piston lock ring is not used to safety the piston of this propeller. The cylinder head has a splined hole in its center (fig. 39). This splined hole, together with several parts, provides a means of safetying the piston. A bolt is splined along its entire length so that it will fit a splined hole in the center of the piston-gasket nut (fig. 37). A washer is fixed to this bolt at its front end to center the bolt properly in the hole in the cylinder head. A spring holds the bolt forward through this hole. A locking

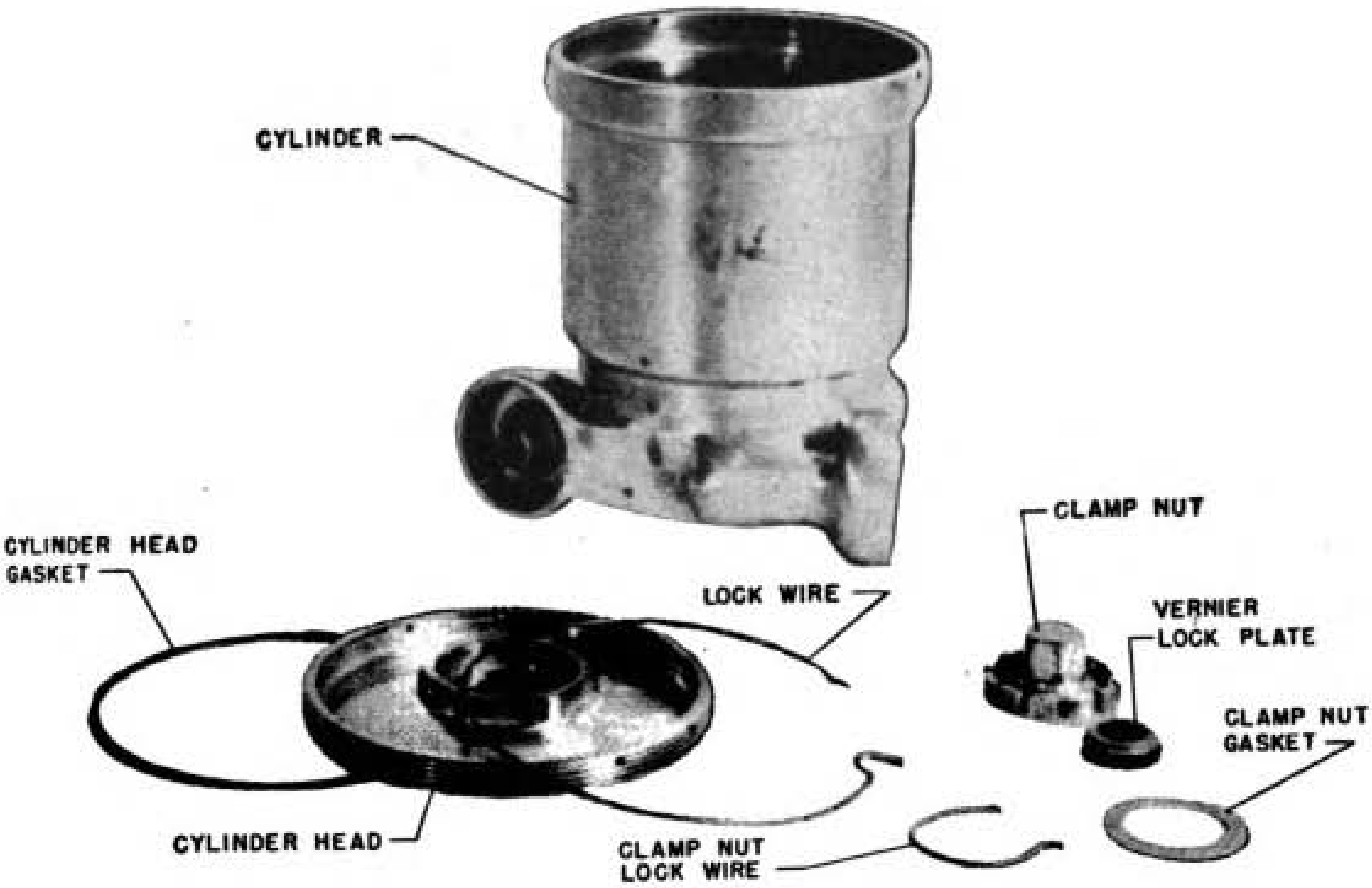


FIGURE 39.—Cylinder assembly.

device fits around the bolt and into the hole in the cylinder head. This device, called the vernier lock plate, is splined on its outside circumference to fit the splined hole in the cylinder head, and splined on the inner bore to fit the splines of the bolt. With the vernier lock plate installed, a clamp nut threads to the threaded front end of the bolt to hold it firmly to the cylinder head. The clamp nut is locked to the cylinder head by means of a lock wire. When the piston begins to loosen, it turns the piston-gasket nut, which will attempt to turn the bolt to which it is splined. The vernier lock plate forms a splined connection between the bolt and the cylinder head, so that any turning force on the bolt will cause a like turning force on the cylinder head. The cylinder head, however, is locked to the cylinder by a lock wire, and the cylinder is held firmly to the propeller by the mechanical linkage of the pitch-changing mechanism. Thus, the splined bolt and the vernier lock plate safety the piston and the piston-gasket nut to the cylinder head, which is in turn safetied to the cylinder by means of a lock wire. Although the bolt moves back and forth with the cylinder, it never becomes disengaged from the piston-gasket nut. Piston-gasket nuts and cylinder heads may be either flat or dome-shaped.

c. Propeller with spring-return assembly.—The type of constant-speed propeller described is similar in most other respects to the two-position propeller. However, another type of constant-

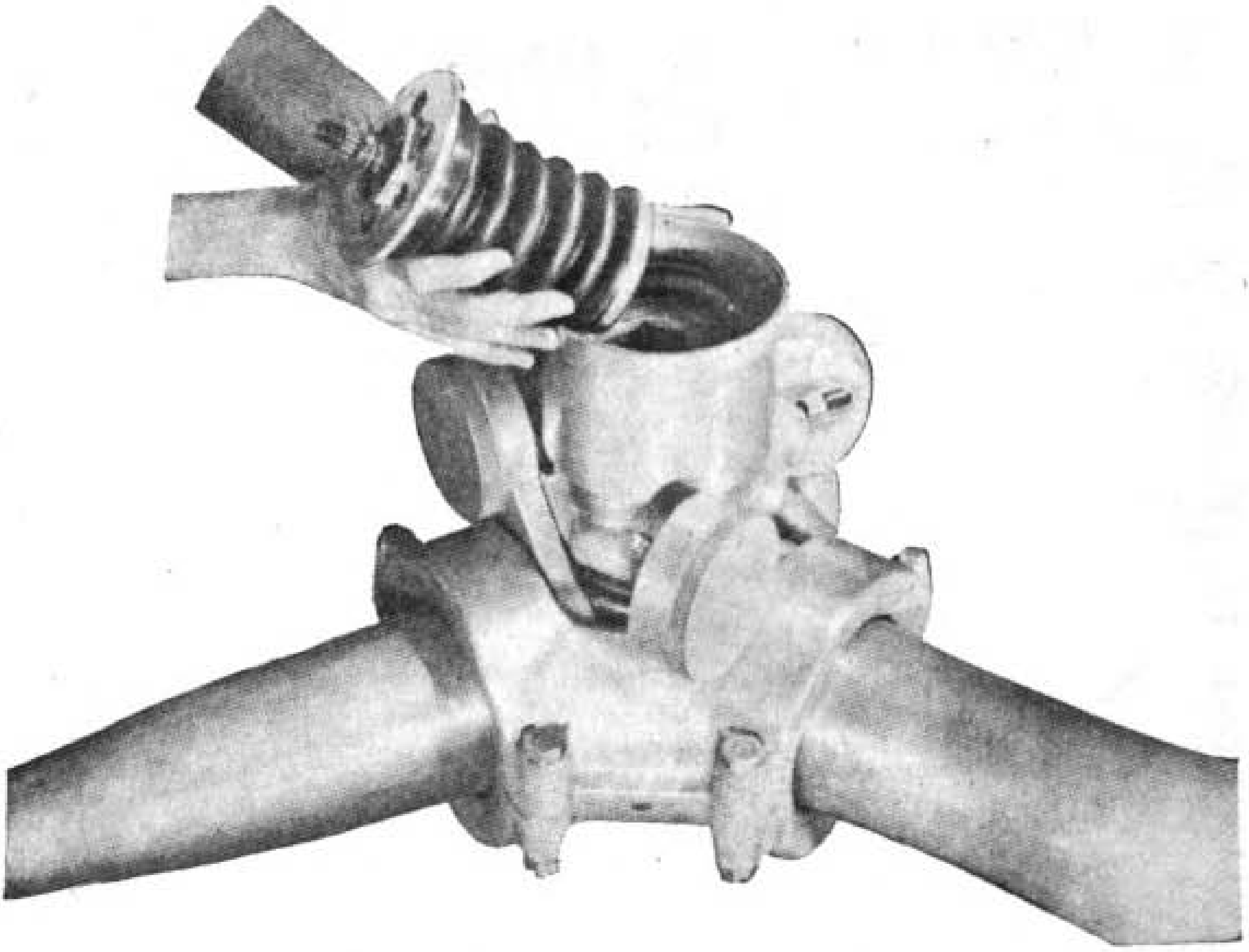


FIGURE 40.—Spring-return assembly.

speed propeller employs a heavy-spring assembly in the pitch-changing mechanism to obtain a greater blade-angle range.

(1) This propeller is the same as the constant-speed propeller already described, except that the action of a spring-return assembly is added to obtain a blade-angle range of 20°. This spring assembly is installed inside of the propeller piston. Two springs, one inside of the other and coiling in opposite directions, are necessary to prevent "surging" during compression and release of the spring assembly. These two springs are placed between the piston-gasket nut and a spring puller plate fastened to the rear end of the splined bolt, in this case a spring puller bolt. When governor oil pushes the cylinder forward, shifting the propeller into low pitch, the puller bolt and plate move forward with the cylinder. The springs are therefore compressed between the puller plate and the piston-gasket nut, which is threaded to the stationary piston (fig. 40). The compressed springs will aid the operating force of the counterweights in returning the propeller to high pitch. The spring force is greatest in full low pitch, becoming less and less as the propeller shifts toward high pitch. About two-thirds of the way from full low to full high pitch, the spring force

is discontinued and the counterweights alone provide the operating force.

(2) The spring-return assembly is needed with 20° propellers because of the increased slope of the counterweight cam slots. In low pitch, the counterweights are closer to the axis of rotation of the propeller than they are in the low-pitch position of a 10° or 15° constant-speed propeller. As a result, for the same rpm the centrifugal force developed on the counterweights of 20° propellers is less. Heavier counterweights could be used, but it is preferable to obtain additional operating force through the use of the spring-return assembly.

26. Service use.—Hamilton standard constant-speed propellers are used for the most part on some advance-training, cargo, and observation airplanes. Constant-speed 20° propellers are used on engines requiring a greater blade-angle range than is possible with constant-speed propellers that do not have a spring return assemly. Where a still larger blade-angle range is required, and the feathering feature is desirable (on multi-engine airplanes), other types of constant-speed propellers, as described in the following sections, are used.

27. Constant-speed governor.—*a. General.*—(1) The Hamilton standard constant-speed propeller governor is geared to the engine crankshaft and is fitted with two flyweights which rotate at a speed directly proportional to the speed of rotation of the crankshaft. The greater the speed of the engine crankshaft, the greater will be the centrifugal force on each flyweight, and the greater the tendency of the flyweight to move outward. A governor speeder spring bears down on the flyweight lobes with a force sufficient to keep each flyweight in balance—that is, upright—at a certain engine speed.

(2) When the engine is operating at such a speed that the centrifugal force on the flyweights exactly counterbalances the force of the spring, the flyweights remain in an upright position (fig. 41①). The governor is then said to be in an "on speed" condition. When the engine rpm increases above this point, the centrifugal force on the flyweights increases, and causes them to move outward, overcoming the force of the spring. The outward movement of the flyweights, in this "overspeed" condition of the governor (fig. 41②), raises a valve in the governor which permits all to flow away from the actuating cylinder in the pitch-changing mechanism of the propeller. As a result the blades are moved to a higher pitch by the counterweights. This increased "bite" of the

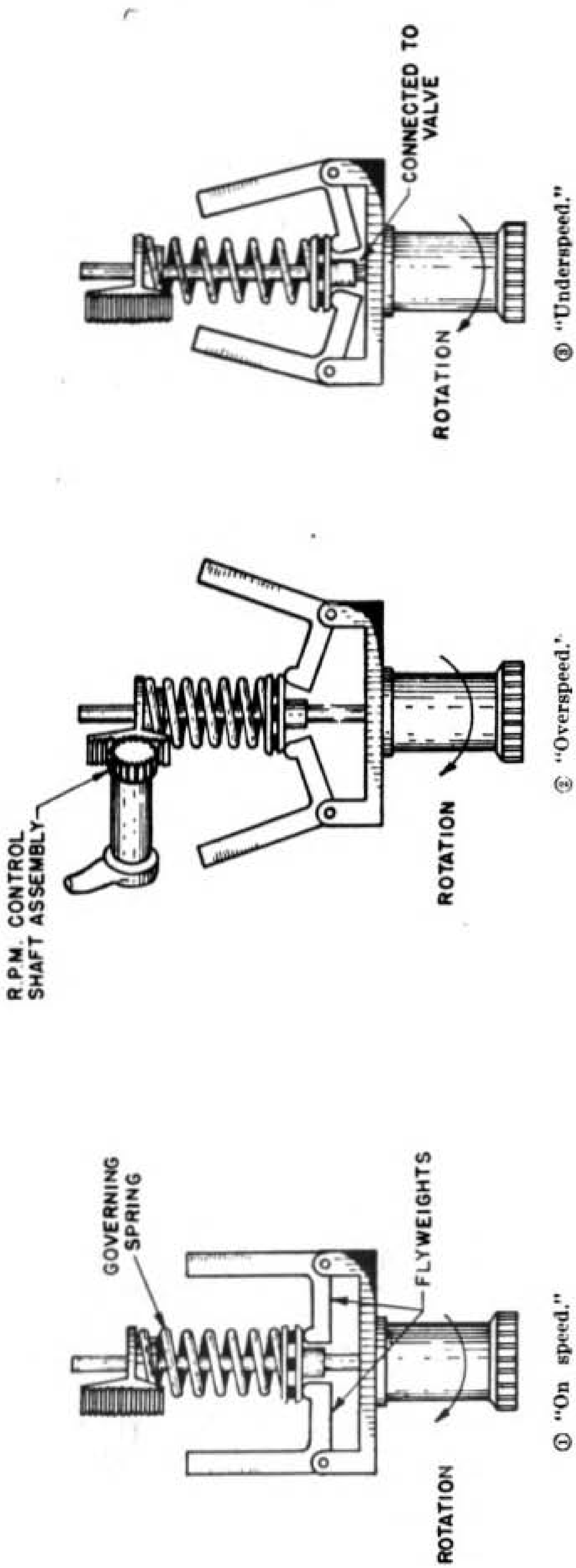


FIGURE 41.—Governor fundamentals.

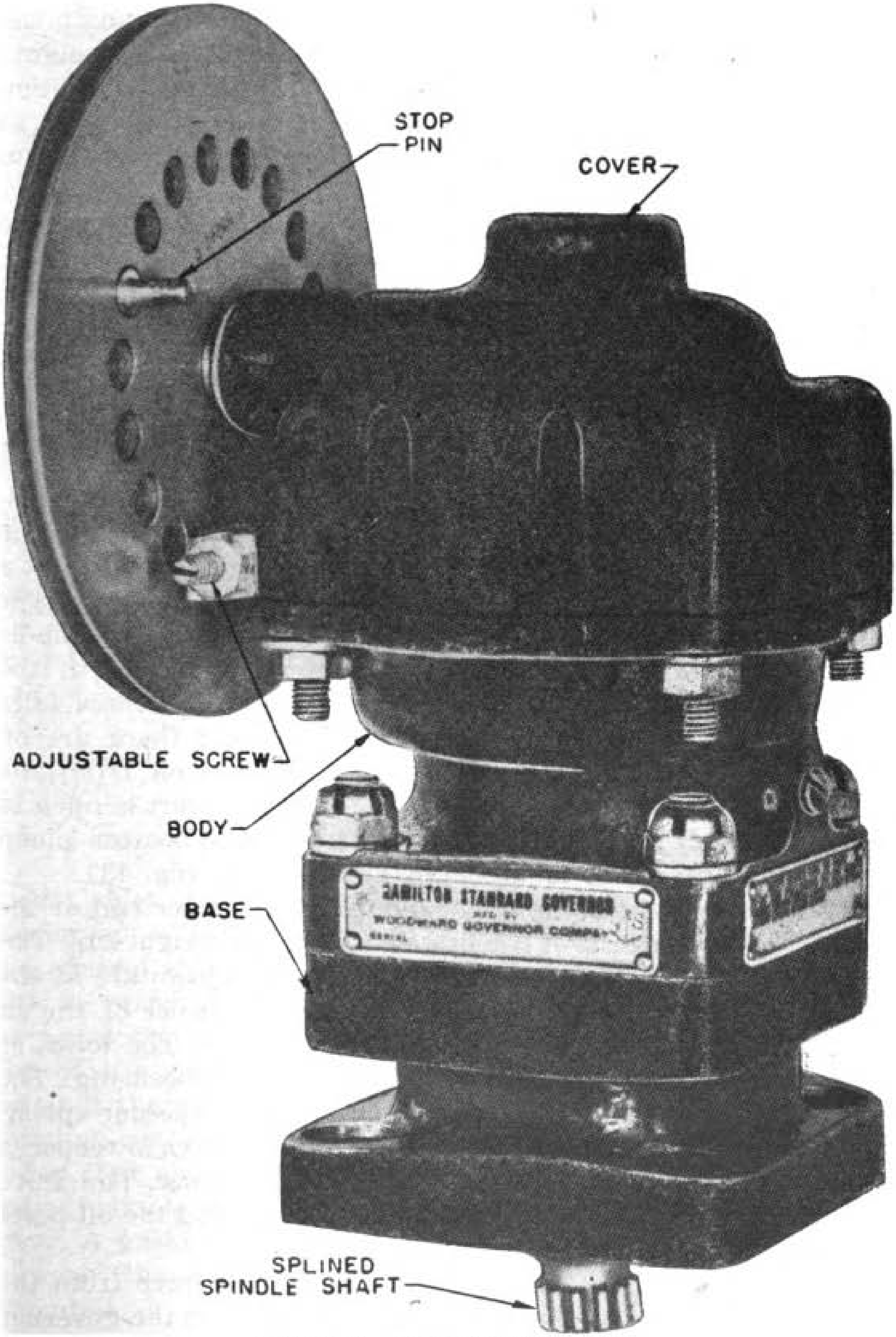


FIGURE 42.—Constant-speed governor.

blades produces a heavier load on the engine, causing rpm to decrease to the original "on speed" value.

(3) When engine rpm decreases below the value foı which the governing spring is set, the spring force moves the flyweights inward, so that the governor is in an "underspeed" condition (fig. 41③). This movement of the flyweights lowers the valve, so that high-pressure oil is directed to the pitch-changing mechanism and the blades are moved to a lower pitch.

(4) By means of a mechanical linkage from the cockpit to the governor, the pilot may vary the compression on the speeder spring. In this manner he may choose the rpm at which he wishes the engine to operate during take-off, landing, and varying conditions of flight.

b. Description.—(1) The case of the constant-speed governor consists of three main parts: the base, the body, and the cover (fig. 42). The base is designed so that the governor may be mounted on a pad on the nose of the engine or on one of the engine accessory pads. Mounted in the body of the governor is the hollow spindle shaft. This spindle shaft is splined at its lower end to fit a standard governor drive shaft from the engine. The gear type booster pump and the flyweight assembly are driven by the spindle shaft. The drive gear of the booster pump is integral with the shaft, and meshes with an idler gear mounted on a hollow idler gear shaft. Above and below the pump drive gear there are oil ports. The upper port permits the high-pressure oil from the booster pump to enter the spindle shaft. The lower port is open to the propeller oil line. The pressure created by the booster pump (governor oil pressure) is limited by a relief valve (fig. 43).

(2) The flyweight assembly is mounted on the upper end of the spindle shaft. It consists of two flyweights and a flyweight cup. The cup causes the oil which accumulates in the head to rotate at the same speed as the flyweights. This prevents turbulence of the oil from interfering with the action of the flyweights. The lobes of the flyweights bear against the flyweight-valve ball bearing. The flyweight valve screws into a collar upon which the speeder spring exerts its force, so that the valve is moved up and down in response to changes in the two opposing forces in the governor. The valve slides in the hollow spindle shaft, opening and closing the oil ports in that shaft.

(3) In order that the pilot may vary the spring force from the cockpit, an rpm control-shaft assembly is mounted in the governor cover. To the outer end of the control shaft is fitted a pulley. The inner end has a gear whose teeth mate with the speeder-spring

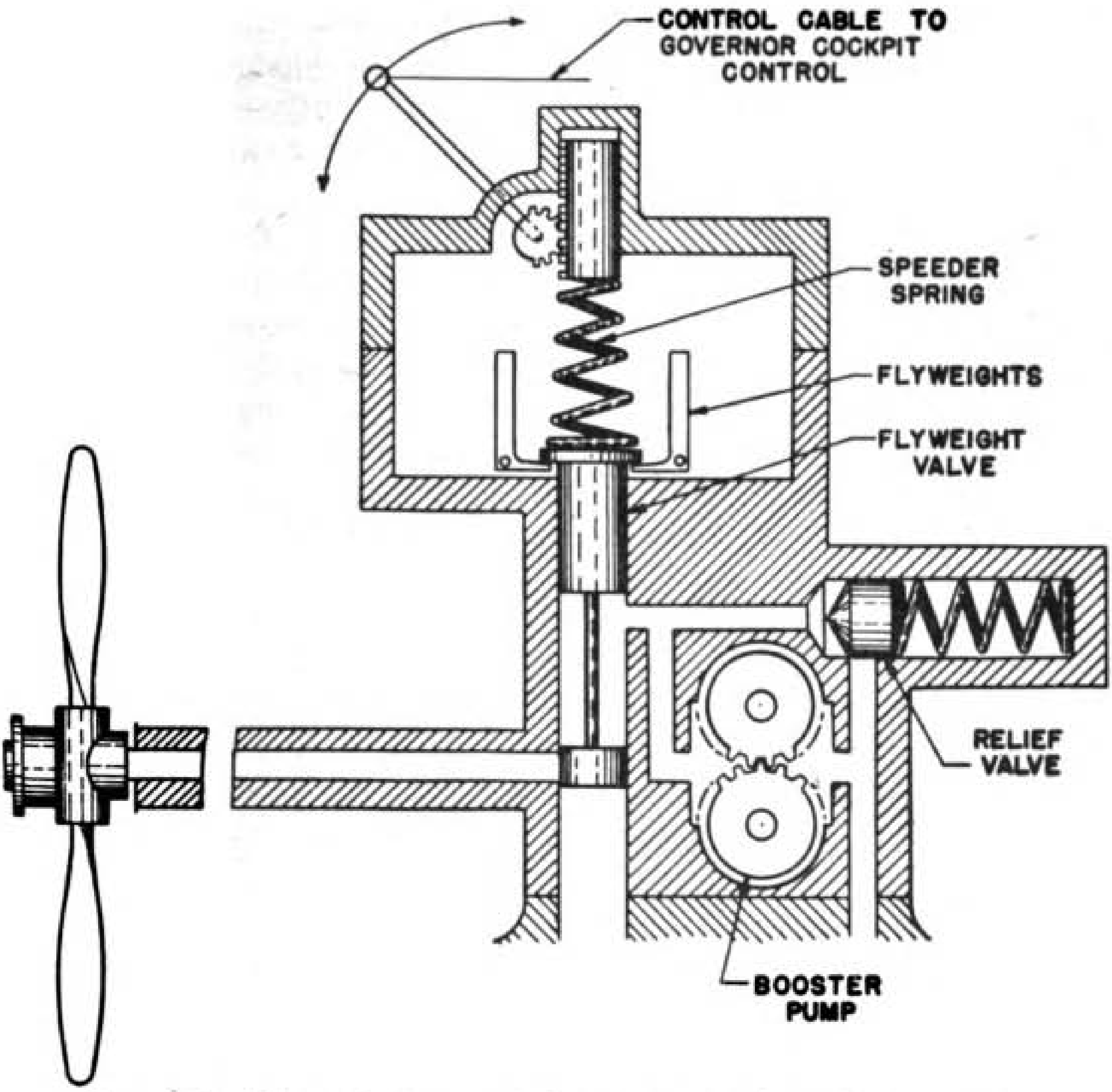


FIGURE 43.—Schematic diagram of the constant-speed propeller governor.

rack. Cables attach the pulley to the propeller cockpit control. Any movement of the cockpit control will rotate the governor pulley and control shaft, and cause the control-shaft gear to move the rack up or down. The rack bears on the upper end of the speeder spring so that its up and down movement will vary the compression of the spring. A stop for the high limit of the governing range of the unit is provided on the control pulley. It consists of a pin that can be located in any one of a number of holes in the pulley. The motion of the pulley is stopped when the pin contacts the adjustable screw threaded through a mount integral with the cover. A gasket between the cover and body section, and another between the body and base sections, complete the governor assembly.

c. Operation.—(1) When the centrifugal force on the flyweights exactly balances the force of the speeder spring, as set by the pilot, the flyweight valve is in such a position that it closes off the ports

to the propeller line (fig. 43). Since oil does not flow either to or from the propeller cylinder, the pitch of the blades is held fixed and engine rpm remains constant. The oil passes through the booster pump and is bypassed through the relief valve to the inlet side of the pump.

(2) If the engine speed decreases, the speed of rotation of the flyweights decreases with the decreasing engine rpm. This causes reduced centrifugal force on the flyweights; hence the speeder spring is allowed to override the flyweights. The flyweights therefore move inward and the flyweight valve moves downward, allowing the oil under pressure to enter the propeller cylinder. Actuated by oil pressure, the pitch-changing mechanism moves the blades to a lower pitch, and the engine regains and holds its rpm at the desired value.

(3) When the engine rpm tends to increase, causing an "overspeed" condition, the centrifugal force on the flyweights is increased and overrides the speeder-spring load. The flyweights move outward, lifting the flyweight valve and opening the propeller port to the drain port. Oil flows from the propeller cylinder, permitting the pitch-changing mechanism to move the blades to a higher pitch and thus bring the engine rpm back to the desired figure.

(4) Under actual operating conditions, the flyweight-valve, speeder spring system is rarely in the "on speed" position. Owing to more or less constant change in altitude, to bumpy air, to variations in engine horsepower, or to maneuvers of the airplane, the constant-speed governor is continually operating to cause changes in the propeller blade angle necessary to maintain the engine rpm constant.

28. Principle of operation.—*a*. In the operation of the pitch-changing mechanism, governor oil pressure is the controlling force that moves the blades toward the low-pitch position. The centrifugal twisting moment of the blades toward low pitch is an additional force that tends to decrease the blade angle. The blades of the constant-speed propeller without a spring-return assembly are moved toward the high-pitch position by centrifugal force acting on the counterweights attached to the blade brackets. When a spring-return assembly is used, the additional spring force aids the operating force of the counterweights in moving the blades to a higher pitch.

b. If the governor is in an "on speed" condition, that is, if the engine is rotating at the rpm that the pilot has selected by means of the cockpit control, the governor will not allow oil to flow either

to or from the propeller cylinder. A volume of oil is trapped in the cylinder, and the pitch of the blades is held fixed. When the engine rpm decreases, the governor allows oil to flow to the propeller cylinder. Governor oil forces the cylinder to move forward, and the counterweight bearing shafts are pulled forward in the cam slots of the counterweight brackets, which are attached to the blade butts. The movement imparted to the brackets by the bearing shafts results in rotary movement of the blades toward a lower pitch. The engine rpm increases until it is again "on speed", and governor oil ceases to flow to or from the propeller cylinder. On the other hand, any increase in engine rpm from this "on speed" condition causes the flyweight valve to connect the propeller port to the drain port. Centrifugal force on the counterweights and the force of the spring-return assembly when one is used, being unopposed by governor oil pressure, cause the counterweights to fly outward and the cylinder to move rearward. The mechanical linkage between the cylinder and the blades—counterweight-bearing shaft, counterweight bracket, index pins, and blade bushings—turns the blades toward a higher pitch. An "on speed" condition again exists, and a volume of governor oil is trapped in the propeller cylinder to hold the blade pitch constant.

29. **Adjustment of controls.**—*a. General.*—The governor and the governor controls are properly adjusted when each setting of the governor control gives engine rpm corresponding exactly with the particular setting. That is, when the governor control is set at take-off rpm, the tachometer will show that the engine is actually operating at take-off rpm; when the control is set at cruising rpm, the engine will operate at cruising rpm, and so forth. The throttle and mixture controls (and the controls of the supercharger, if one is used) must also be in their proper positions to provide sufficient manifold pressure. In checking range of operation or control adjustment, it is important that at no time should engine rpm or manifold pressure exceed their rated values.

b. Adjustment of high-rpm stop.—The high-rpm stop of the governor is adjusted to give the proper high rpm for the particular engine and propeller. It is necessary only to connect the governor cockpit control to the pulley or control arm of the governor to have proper adjustment of the control (see installation procedure, par. 31). However, if the high-rpm stop should get out of adjustment, necessary corrections will have to be made.

c. Readjustment of high-rpm stop.—If it is necessary to readjust the high-rpm stop, the following procedure will be followed:

(1) For trial setting, place the governor cockpit lever in the extreme rear position.

(2) Turn the pulley or control arm attached to the governor control shaft in a clockwise direction to the minimum-rpm position or allow it to assume this position. When the pulley or control arm is in this position, the governor speeder spring is as little compressed as it can be.

(3) Connect the control cable or rod extending from the cockpit lever to the pulley or control arm attached to the governor control shaft.

(4) Loosen the increase-rpm stop screw and shift it away from the stop pin on the pulley.

(5) Start and warm up the engine.

(6) With the engine warmed up, move the cockpit lever slowly forward until the engine tachometer reads the desired take-off rpm.

(7) Stop the engine, taking care that the setting of the governor lever in the cockpit is not disturbed.

(8) Adjust the increase-rpm stop screw toward the stop pin until it bottoms against the stop pin of the pulley. If the stop pin of the pulley is out of position, it will be placed in a hole in the pulley so that the increase-rpm stop may be made to bottom against the pin.

d. Flight test.—A flight test must be made to insure that the governor is adjusted properly. If during flight the rated rpm cannot be obtained or if excessive rpm is encountered, readjustment of the controls is again necessary. The high-rpm stop is loosened and shifted away from the pulley, lever, or housing. Another trial flight is made and the cockpit control lever adjusted until rated rpm is obtained, the control quadrant being marked at this position. After the airplane is landed and the engine stopped, the cockpit control lever is adjusted to the marking on the quadrant, and the governor stop reset. The mechanical linkage between the governor and the cockpit lever is then readjusted to give the ⅛-inch play indicated in paragraph 31*d*(5). The proper high-rpm setting is very important to prevent engine overspeeding and to give adequate power for take-off. If this setting is properly made, the other settings will be sufficiently accurate.

e. Adjustment of propeller to low-pitch stop.—Occasionally the propeller low-pitch stop is set so high that the blades are mechanically prevented from going to a low-enough pitch to obtain rated rpm. If a slight movement of the cockpit control lever from the maximum-rpm position in the decrease-rpm direction has no effect on the engine rpm, this is probably the case. Obviously no governor

adjustment can correct this condition. The propeller low-pitch stop must be readjusted according to applicable Technical Orders.

f. Caution in movements of controls.—All movements of the throttle and propeller cockpit control should be made slowly. Before checking the governor control, instructions for the particular airplane, engine, and propeller should be consulted in Technical Orders. If the governor control is not working properly, the necessary adjustments of the high-rpm stop or the mechanical linkage must be made.

g. Synchronization of engines.—The engines of a twin-engine or multi-engine airplane are synchronized when they are operating at the same rpm. Poor engine synchronization may be caused by improperly adjusted governor controls or by faulty operation of a governor or a propeller; but it also may be traced to faulty carburation, faulty ignition, or other engine troubles.

30. Preflight operation.—*a.* Before each flight, an operations check of the propeller controls and governor is made. This check is accomplished in the following manner:

(1) Before the engine is started, the propeller control will be placed in the positive high-pitch (low-rpm) position. After starting, the engine is run for at least 1 minute with the control in this position. This is necessary in order to avoid possible lack of oil to the master rod bearings of the engine, inasmuch as oil from the engine is necessary to hold the blades in a low pitch.

(2) The propeller control is shifted to the take-off rpm position, causing the propeller to shift to full-low pitch. The warm-up must be at the required rpm and to the proper temperature as specified in operating instructions for the particular type of engine.

(3) When sufficiently warmed up, the engine should be run up to approximately 1,600 rpm (except where limitations have been listed on specific engines) with the throttle in an intermediate position.

(4) Move the propeller control to positive high pitch and observe the decrease in engine rpm as indicated by the tachometer. It is also good practice to have an observer stationed outside the airplane at a point where the movement of the cylinder can be observed. He may signal the rearward movement of the cylinder. When no further decrease is indicated on the tachometer, the propeller is in full high-pitch (low-rpm) position.

(5) Move the propeller control to take-off rpm position and observe the outward movement of the cylinder and the increase in engine rpm. When no further increase is indicated on the tachometer, the propeller is in full low-pitch (high-rpm) position.

(6) Return the propeller control to its original position, noting that the engine speed returns to 1,600 rpm (or the rpm specified for the particular engine).

(7) Leaving the propeller control in this position, slowly move the throttle back and forth. The tachometer should show a fairly constant engine speed of 1,600 rpm (or rpm specified for the particular engine), indicating that the pitch change to compensate for variations in manifold pressure is occurring. The preflight operations check is thus completed.

b. The propeller control is placed in the positive high-pitch position prior to stopping the engine for the same reasons as were indicated for the two-position propellers: the cylinder covers the piston and prevents corrosion of it, and the piston and cylinder are emptied of oil. In addition, the compression is removed from the spring return assembly.

31. Removal and installation.—*a. Removal of propeller.*—The removal of the Hamilton standard constant-speed propeller is accomplished in the following manner:

(1) Always make certain that the ignition is OFF before starting removal. Check to see that the blades are in the high-pitch position. If not, use a blade beam on each blade to move them to high pitch. Care should be exercised to insure that all blades are moved at the same time. In the high-pitch position the cylinder is not full of oil, and the piston is in a position such that the wrench for unscrewing it may be installed. It is extremely important that a propeller using a spring-return assembly be in the full high-pitch position before beginning the removal. This will insure that all compression on the spring-return assembly is removed. This will prevent the threads of the clamp nut from being stripped by the force exerted on the puller bolt by the compressed spring-return assembly.

(2) Remove the clamp-nut lock wire, unscrew the clamp nut, and remove the clamp-nut gasket.

(3) Remove the vernier lock plate. Failure to remove the vernier lock plate before attemping to unscrew the cylinder head may result in serious damage to the splined bolt or cylinder head. (fig. 44).

(4) Remove the cylinder-head lock wire and unscrew the cylinder head. Remove the cylinder-head gasket. Have a pail handy to catch the oil that remains in the cylinder.

(5) When removing propellers not having a spring-return assembly, remove the splined bolt; unscrew the piston-gasket nut, and then remove the two piston gaskets. With propellers having a

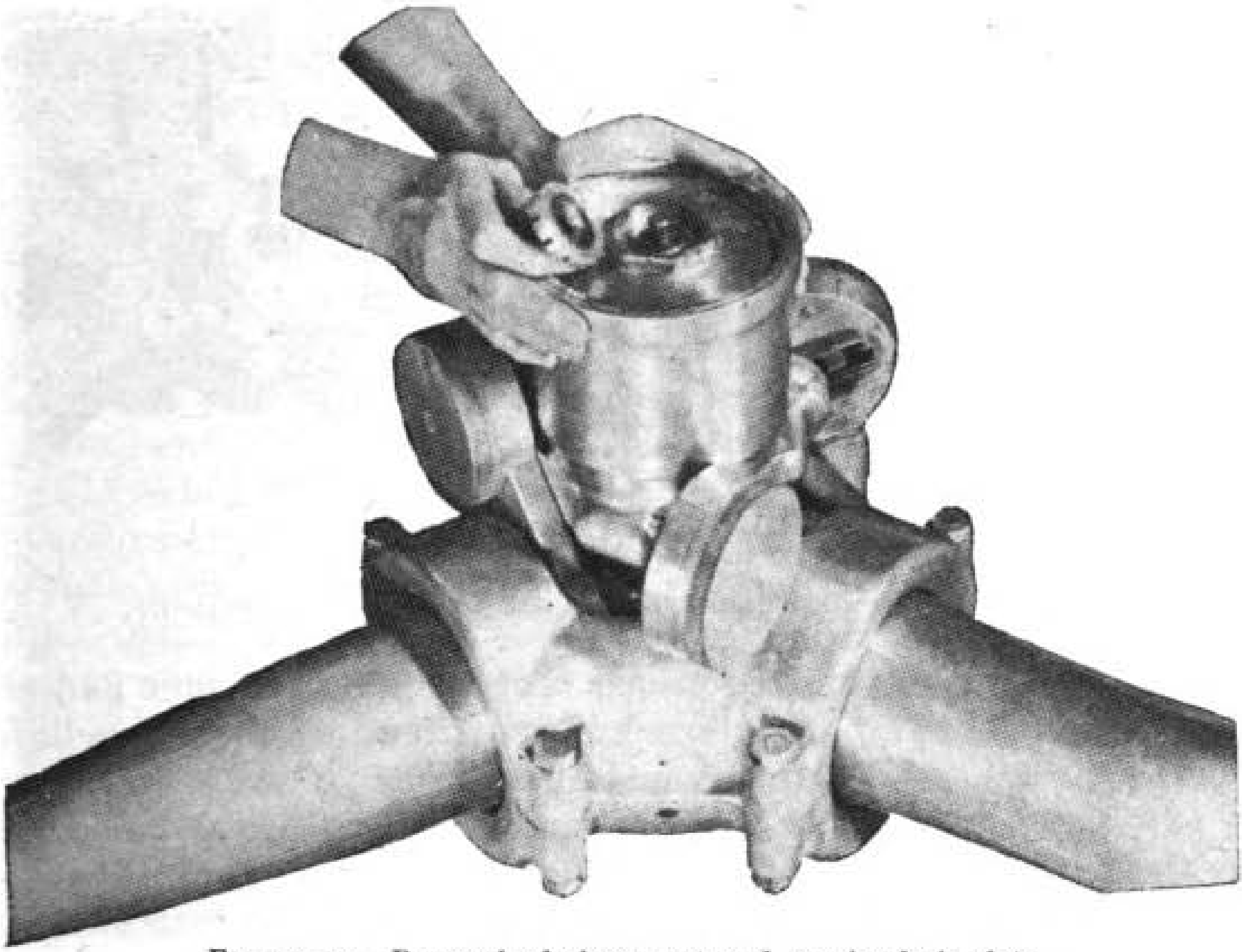


FIGURE 44.—Removal of clamp nut and vernier lock plate.

spring-return assembly, unscrew the piston-gasket nut; remove the spring-return assembly, and then remove the two piston gaskets.

(6) Install the piston wrench and unscrew the piston. This will start the propeller off the propeller shaft.

(7) Using a hoist and slings, slide the propeller slowly forward on the propeller shaft and remove it, taking care not to damage the propeller-shaft threads. Care should also be taken not to hit the short oil supply pipe installed in the end of the shaft.

(8) Remove the rear cone and rear-cone spacer (if used) from the propeller shaft.

(9) If the piston is to be removed, the propeller must be put in the low-pitch position. This is necessary so that there will be an open space at the base of the cylinder. Through this space the snap ring may be removed from its groove in the spider. The piston is then moved forward through the cylinder, and the front cone and snap ring are disassembled from the piston. The front cone and snap ring may be removed through the space at the base of the cylinder, and the piston may be removed from the cylinder (fig. 45).

b. Installation of propeller.—The proper procedure for installing a Hamilton standard constant-speed propeller is as follows:

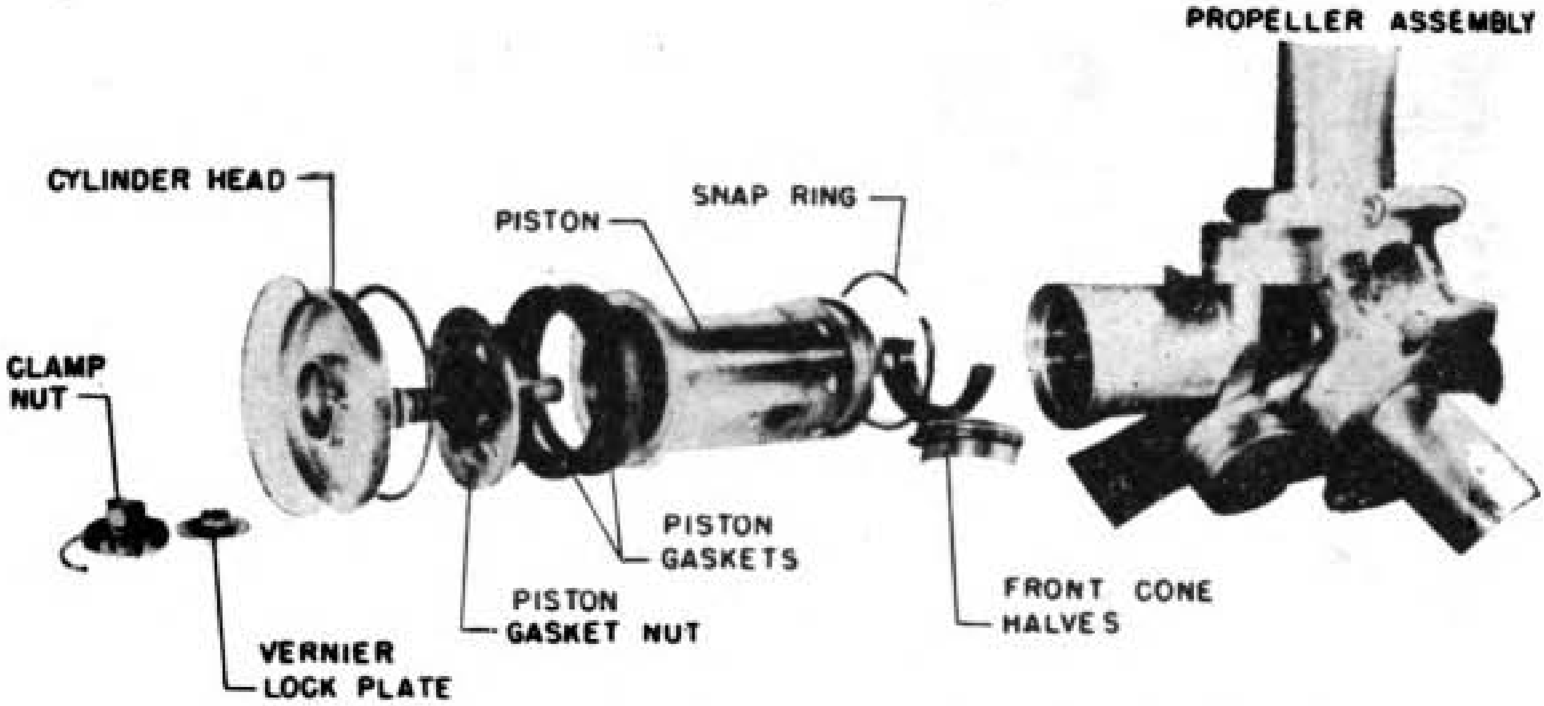


FIGURE 45.—Removal and installation chart, constant-speed propeller.

(1) Check to see that the proper propeller-shaft adapter and oil supply pipe for the particular engine—with or without propeller-shaft ventilation—is correctly installed.

(2) Install the bronze rear cone and rear-cone spacer (if used) on the propeller shaft against the engine thrust nut. Both the rear cone and its seat are left dry.

(3) Having made sure that the splines are free from defects, oil the splines of the propeller shaft and hub, and oil the front cone and its seat with light engine oil.

(4) Aligning the wide groove of the hub with the wide spline of the propeller shaft, slide the propeller well back against the rear cone.

(5) If the piston is not already installed, the propeller must be put in the low-pitch position. Great care must be taken not only to move all the blades at the same time, but also not to pull the propeller off the shaft when the piston is not holding it securely to the shaft. Coat the threads of the piston with thread lubricant. The piston will then be inserted through the cylinder, and the snap ring and front cone assembled on the piston through the opening at the base of the cylinder.

(6) Carefully start the piston on the propeller shaft, making sure that the oil-supply pipe correctly enters the hole and seal in the false bottom. If the cylinder is correctly aligned and the piston or shaft threads are not damaged, the piston will screw on easily. In no case should force be used to tighten the piston if there is binding or indication that the threads are not properly started. When the piston is properly started as far as it will go by hand, put the propeller in the high-pitch position

(7) For final tightening of the piston, a force of approximately

175 pounds should be applied at the end of a 4-foot bar. Do not in any case attempt to tighten the piston by hammering on the end of the bar.

(8) Put the propeller in the low-pitch position, and install the snap ring in the groove in the spider through the opening at the base of the cylinder.

(9) Put the propeller in the high-pitch position.

(10) Install the inboard and outboard piston gaskets over the forward end of the piston.

(11) When installing a propeller which does not have a spring-return assembly, install the piston-gasket nut. Using the special wrench provided and a 2-foot bar, tighten this nut to an oil seal. Then install the splined bolt in the splined hole of the piston-gasket nut. With propellers having a spring-return assembly, install the spring-return assembly and tighten the piston-gasket nut to an oil seal, using the special wrench and a 2-foot bar.

(12) Place the cylinder-head gasket on the cylinder head with the asbestos toward the cylinder head. A light coating of grease may be used to hold this gasket in place.

(13) Screw the cylinder head on the head on the cylinder. The special wrench and a 2-foot bar should be used to tighten the cylinder head to an oil seal. As the cylinder head is tightened, the clamp washer on the splined puller bolt enters the guide on the underside of the cylinder head, properly centering the bolt.

(14) Lock the cylinder head to the cylinder by means of the cylinder-head lock wire.

(15) Lock the splined puller bolt to the cylinder head by means of the vernier lock plate. By turning this lock plate one cog at a time, a combination will be found which will allow the lock plate to be pushed in place. The groove and ring on one side of the lock plate are to facilitate its removal and should be toward the front.

(16) Place the clamp-nut gasket in the cylinder-head face.

(17) Thread the clamp nut on the threaded end of the splined puller bolt. The clamp nut should be tightened sufficiently to hold the clamp washer on the splined puller bolt tightly against the cylinder head, and to provide an oil seal. Care should be taken not to tighten this nut too much.

(18) Lock the clamp nut with its lock wire.

(19) A check of all lock wires and cotter pins completes the installation of the propeller.

c. Removal of governor.—Steps in the removal of the Hamilton standard constant-speed propeller governor are:

(1) Disconnect the cockpit control from the governor. If a pulley is installed on the governor, the pulley will be removed from the shaft. Note the index marking on the pulley and the shaft before removal, to insure reinstallation in the same position.

(2) If the governor has external piping, disconnect the pipe connections.

(3) Remove the four mounting-stud nuts.

(4) Remove the governor. In some installations the fit is so close that it is impossible to raise it high enough to clear the mounting studs. In these cases, the usual procedure is to remove the cover of the governor. This is done by removing the four nuts and palnuts which fasten the cover to the body. The cover may now be removed. As the cover is lifted, the control shaft should be turned counterclockwise (looking at the face of the pulley). The purpose of this is to disengage the speeder-spring adjusting rack and the control shaft. If the cover is removed with the flyweight-valve speeder-spring assembly, it cannot be raised high enough to pull the flyweight valve out of the spindle shaft and still keep these two parts in alignment. This alignment should be kept in order to prevent side loads which might bend the flyweight valve.

d. Installation of governor.—Before beginning the installation of a constant-speed governor, two important checks should be made. There are two oil ports marked *A* and *B* in the base of the governor to conduct oil from the engine to the governor pump. However, only the *A* port or the *B* port is used, depending upon the rotation of the governor drive shaft from the engine. If the drive shaft rotates *clockwise*, the hole marked *B* is plugged; if it rotates *counterclockwise*, the hole marked *A* is plugged. Before beginning the installation, check the rotation of the drive shaft and see that the proper hole is plugged. When plugs are to be removed or installed the base of the governor must be removed. The governor spindle shaft should be checked for freedom of movement, since low temperatures and improper fit of bearings will cause governors to bind. These checks having been made, the installation may be performed. During installation, a primary precaution should be observed: make sure that the governor turns freely when assembled to its drive on the engine. The steps in the installation are as follows:

(1) Remove the cover from the governor.

(2) Remove the cover from the surface on which the governor is to be mounted and place the governor in position on the mounting studs.

(3) With the governor in place, screw the governor securing

nuts on the mounting studs and run them down fingertight. It is essential to tighten these nuts down evenly and not too tightly. Frequent checks of the spindle shaft for freedom of movement and backlash should be made during the tightening of the nuts.

(4) When the governor has been properly fastened, without binding, the nuts will be safetied with safety wire or palnuts, depending upon the type of installation.

(5) Moving the cockpit control about ⅛ inch from its full forward position, and turning the pulley until the high-rpm stop pin rests against the adjustable screw on the governor housing, fasten the cockpit control to the pulley without play.

(6) The foregoing procedures are general instructions for governor installation. The installation of a governor on a particular airplane will be in accordance with the installation drawings covering the particular airplane. The checks and precautions noted are of extreme importance.

32. **Inspection and maintenance.**—Except for some variations due to differences in construction, the inspection, maintenance, and precautions necessary to the efficient functioning of the two-position propellers also apply to the constant-speed propellers. Reference should also be made to section XI. The variations and additional inspections and maintenance are given in the paragraphs that immediately follow.

a. Preflight check-up.—Before each flight, propeller operation is checked as described in paragraph 30.

b. Oil and grease leaks.—After the daily or preflight warm-up, the propeller is inspected for oil and grease leaks. Any leaks must be corrected before flight. The most probable leaks, and their cause and correction, are as follows:

(1) Oil leaking around the cylinder head may be due to a loose cylinder head or a damaged cylinder-head gasket. The cylinder head should be tightened or the gasket replaced.

(2) If oil is leaking at the base of the cylinder, the outboard piston gasket is probably defective, or the gasket nut may be loose. Replace gasket or tighten nut.

(3) Oil leaking out of the ventilating holes of the piston may mean that the self-sealing oil seal in the false bottom of the cylinder may be damaged or that the oil seals of the propeller-shaft adapters and oil supply pipes may be defective. The defective seals must be replaced.

(4) If oil is leaking at the clamp nut, the clamp-nut aluminum gasket may be defective or the nut may be loose. The gasket should be replaced, or the nut tightened.

(5) If grease is found on the blade shanks, check to make certain that it is not surplus grease forced into the barrel halves during lubrication of the spider. If it is not surplus gease, a spring-loaded grease retainer is damaged or incorrectly installed. It is necessary to disassemble the propeller to replace a grease retainer; the propeller must therefore be removed from the shaft.

c. Safetying devices.—The visible safetying devices of the propeller should be periodically inspected. These include—

(1) The clamp-nut lock wire.

(2) The cylinder-head lock wire.

(3) Clevis pins and cotter pins of the counterweight bearing shafts.

(4) Clevis pins and cotter pins of the counterweight caps.

(5) Cotter pins of the barrel bolt nuts.

d. Piston looseness.—The procedure for checking the piston of a Hamilton standard constant-speed propeller for looseness is as follows:

(1) With the aid of blade beams, move the propeller into full high-pitch position.

(2) Remove the clamp-nut lock wire, the clamp nut, and the clamp-nut gasket.

(3) Remove the vernier lock plate.

(4) Remove the cylinder-head lock wire, the cylinder head, and the cylinder-head gasket.

(5) Remove the splined bolt and the piston-gasket nut; or remove the spring-return assembly.

(6) Remove the piston gaskets.

(7) Insert the special wrench into the piston. A force of 175 pounds should be exerted on the end of a 4-foot bar. A *steady* pull on the end of the bar should be used to make the check.

(8) Install the piston gaskets, the piston-gasket nut, and the splined bolt; or the piston gaskets and the spring-return assembly.

(9) Install the cylinder-head gasket, the cylinder head, and the cylinder-head lock wire.

(10) Install the vernier lock plate, the clamp-nut gasket, the clamp nut, and the clamp-nut lock wire.

e. Spring-return assembly.—The spring-return assembly must be removed to clean and lubricate the exposed portion of the piston. (See par. 22*d*). This is necessary because the compression of the spring-return assembly makes it impossible to hold the propeller in the full low-pitch position in order to expose the piston.

f. Lubrication.—The lubrication required for this constant-

speed propeller is the same as that required for the two-position propeller (see par. 22).

g. Governor.—Since the governor is a self-contained unit working in oil, it requires little maintenance. The following, however, should be noted:

(1) If external piping is used, it should be checked for security of mounting and to make certain that it is not subject to excessive vibration that might cause failure.

(2) The governor should be checked daily for leakage of oil around the base and head, and the controls should be inspected for loose motion.

(3) The control system and governor should be inspected for security of mounting, proper safetying, and free movement of the governor drive.

SECTION VI

HAMILTON STANDARD HYDROMATIC PROPELLER

Paragraph

33. General.—*a. Comparison with Hamilton standard constant-speed propeller.*—The three main advantages of the Hamilton standard hydromatic propeller (fig. 46) over the Hamilton standard constant-speed propeller are: the large blade-angle range, the feathering feature, and the elimination of the need for external lubrication by having all the moving parts working in oil. Many structural features of the two propellers are the same. The blade and hub assemblies are almost identical, and the governors also are similar in construction and principle of operation. The major difference is in the construction of the pitch-changing mechanism. In the hydromatic propeller the counterweights are eliminated, and the moving parts of the mechanism are completely enclosed (fig. 47). Oil under pressure is used to move the blades to a higher angle. Oil pressure and centrifugal twisting moment are used together to turn the blades to a lower angle.

FIGURE 46.—Hydromatic propeller.

b. Advantages of feathering propellers on multi-engine airplanes.—The blades of a feathering propeller may be turned to such a high angle that they are streamlined in the direction of flight. In this (the feathered) position, the blades act as powerful brakes to stop the rotation of the propeller and the engine crankshaft. This is of particular advantage in case of a damaged engine, inasmuch as further damage caused by a windmilling propeller's

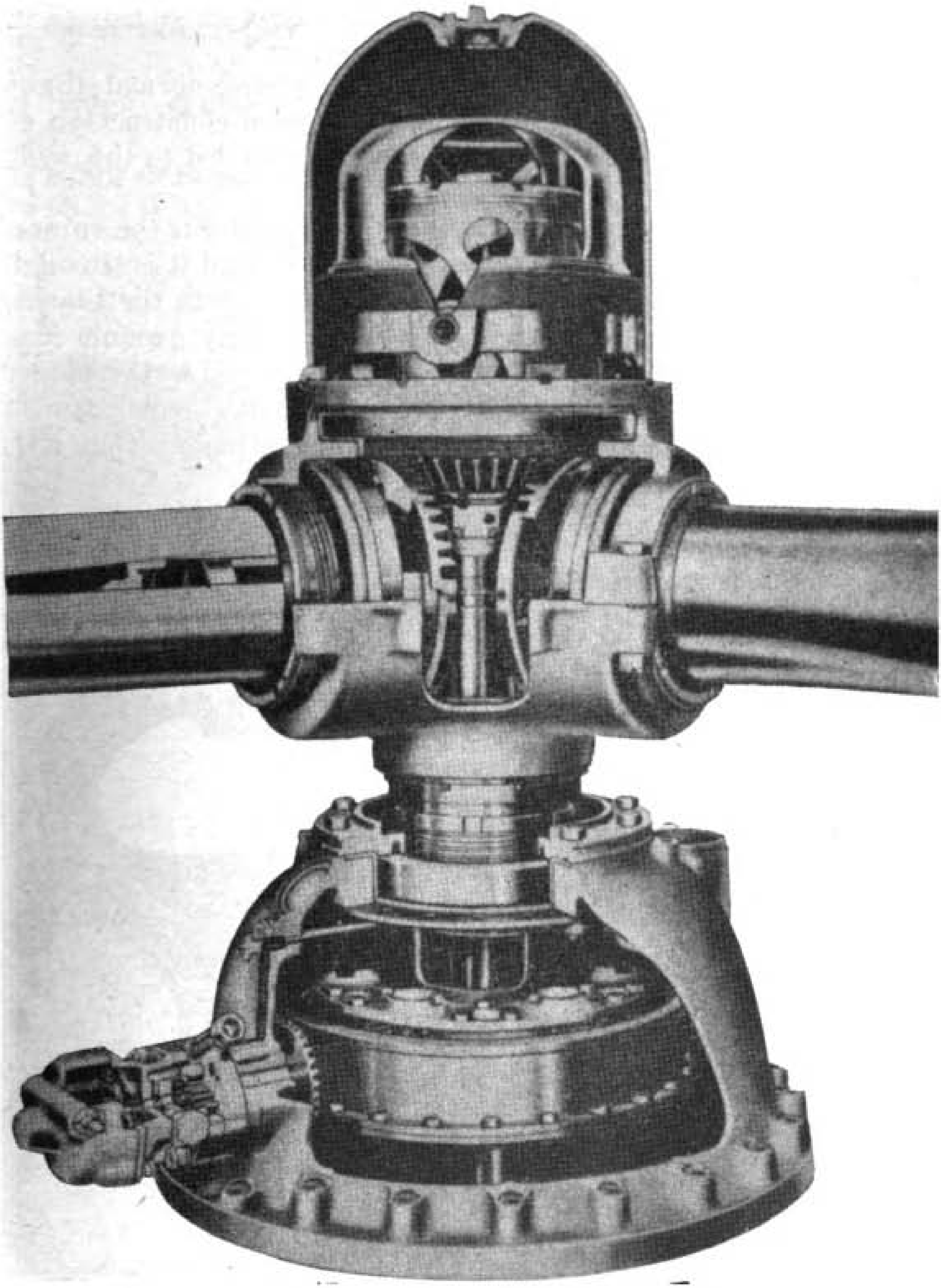


FIGURE 47.—Cutaway of the hydromatic propeller and governor.

cranking the engine is avoided. In addition, the feathered propeller causes the least possible drag on the airplane and prevents the vibration which may occur when a windmilling propeller cranks a damaged engine. As a result, multi-engine airplanes are easier to control in flight when the propeller of an inoperative engine is

feathered. Many twin-engine and most multi-engine airplanes in service are equipped with feathering propellers.

34. Description.—A wide blade-angle range for normal flight operation, the feathering feature, and the rugged construction of the Hamilton standard hydromatic propeller have led to the wide use of this propeller.

a. Spider.—The foundation for the entire propeller is the spider. Its central bore is splined to fit the engine shaft, and it is through these splines that the engine torque is transmitted to the blades. The spider is equipped at both ends with accurately ground cone seats. A groove to receive the snap ring is machined in the spider directly ahead of the front-cone seat. Integral spider arms support the blades and absorb the thrust load from the blades (fig. 48).

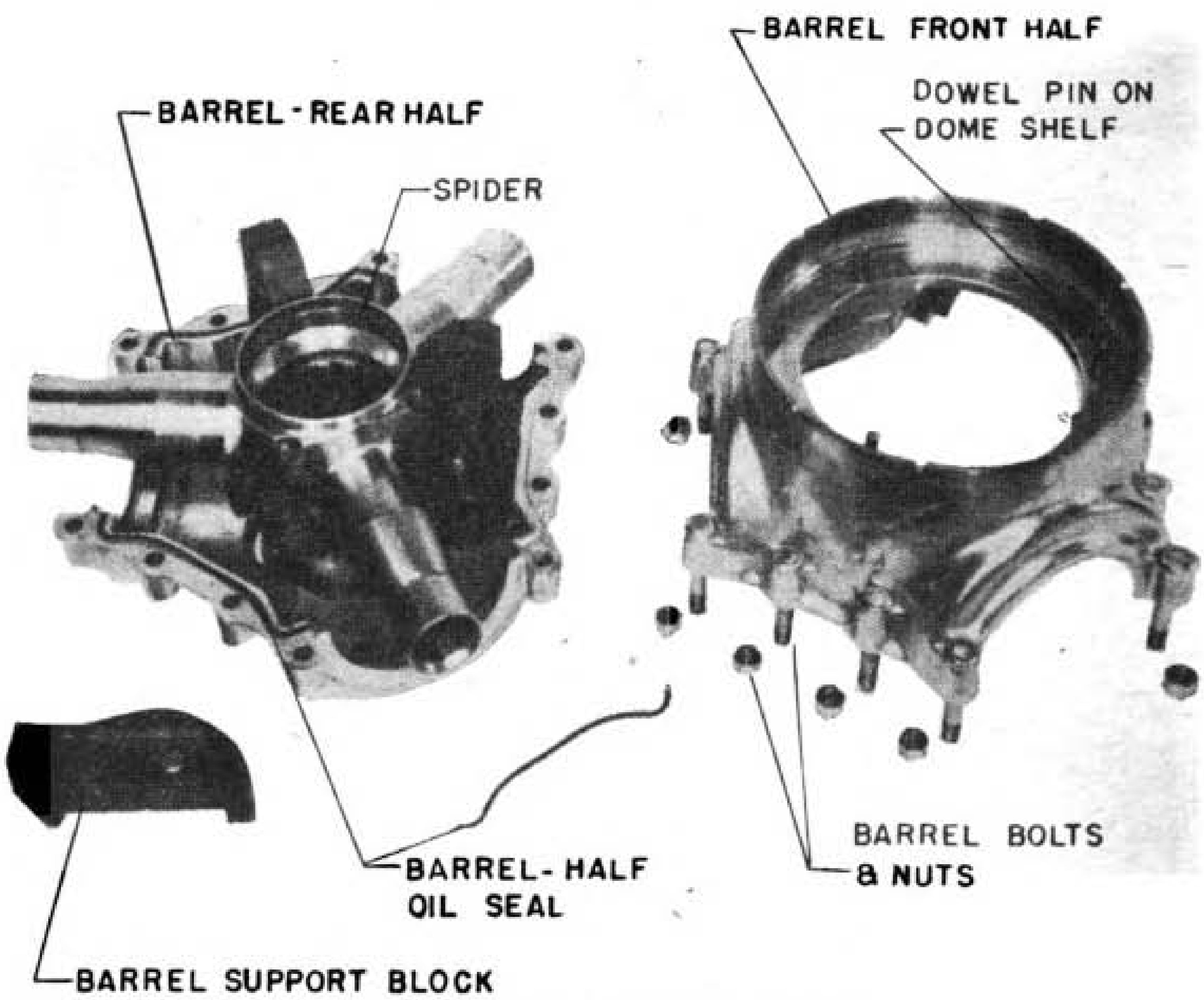
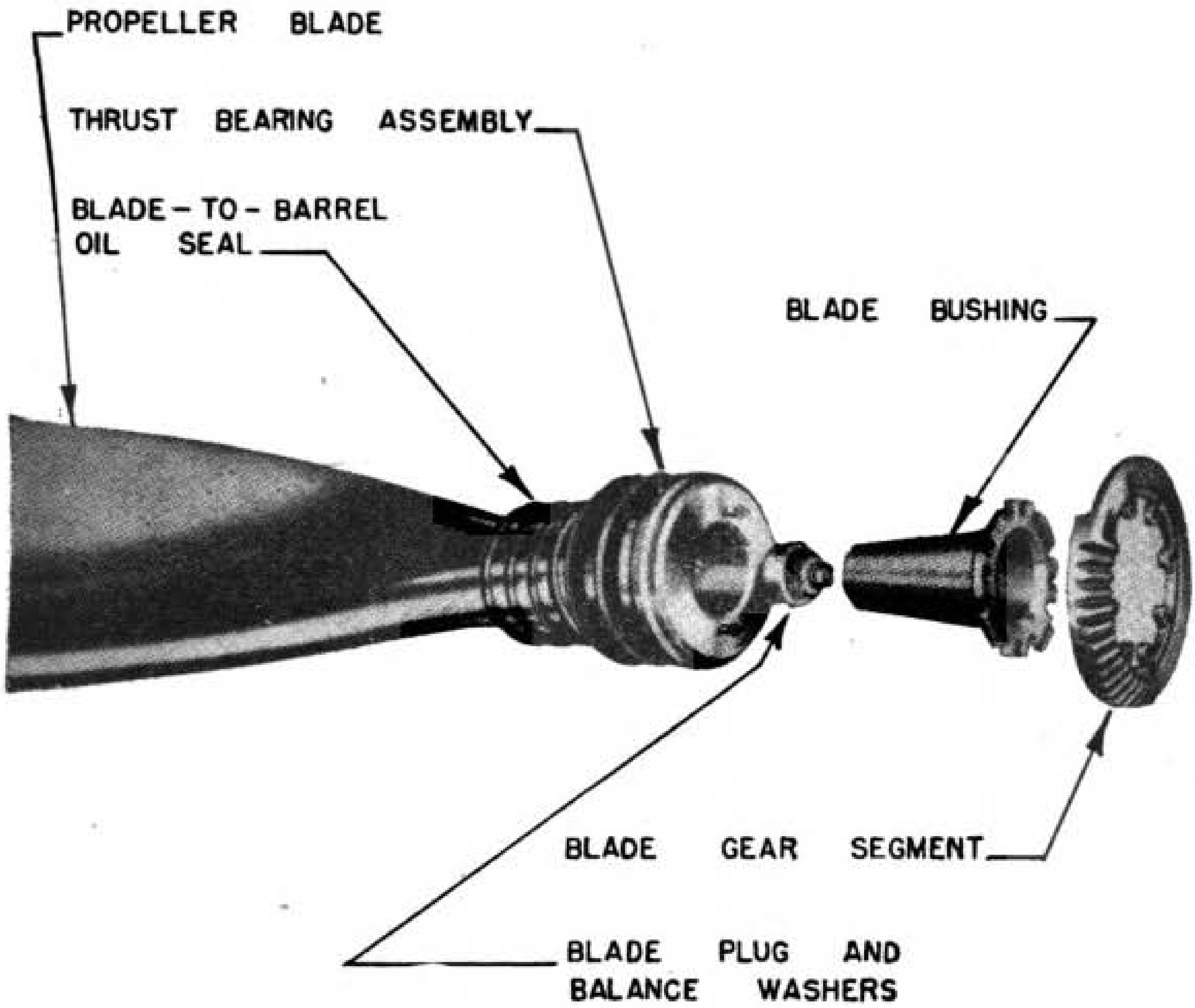


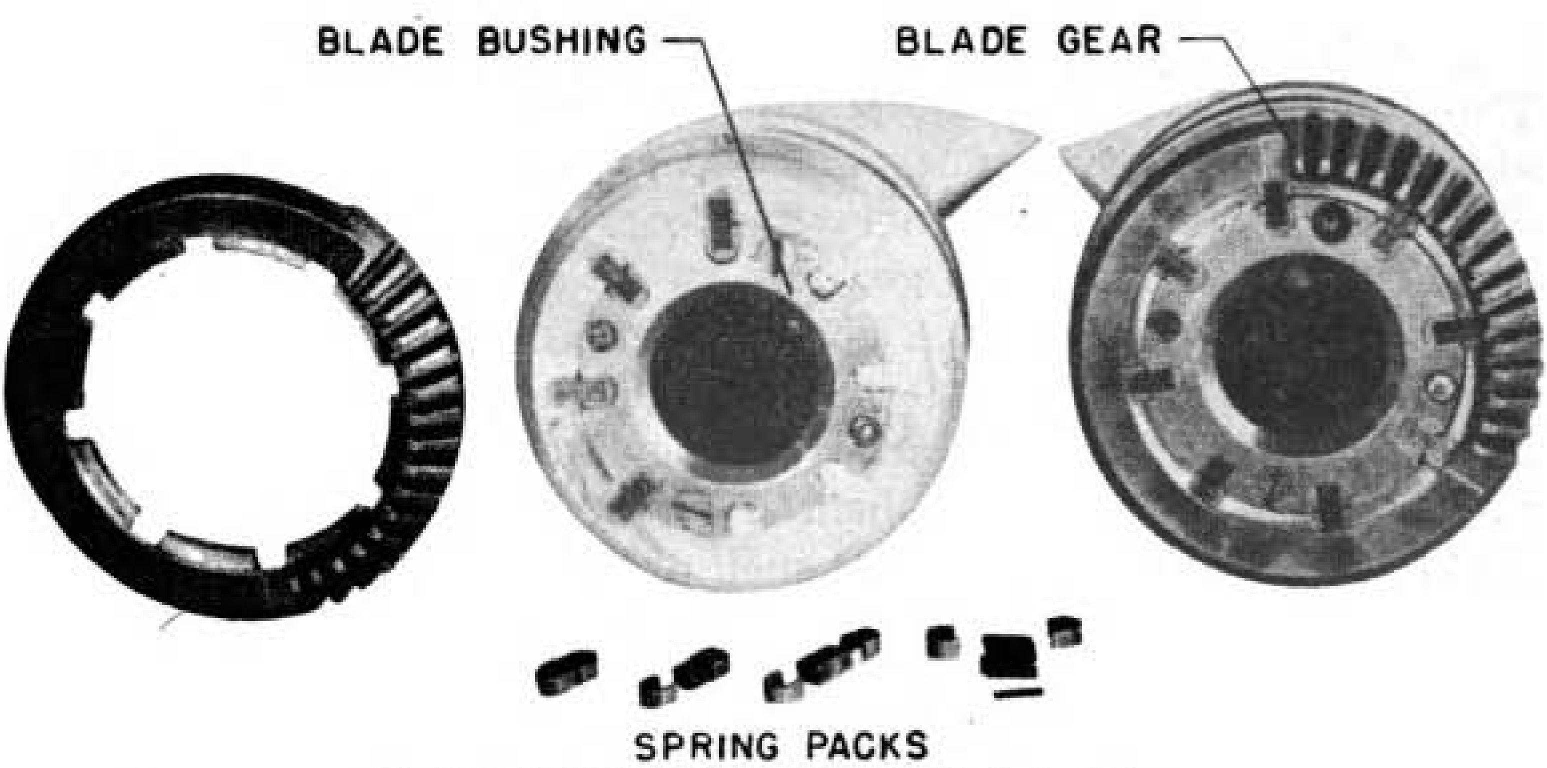
FIGURE 48.—Spider and barrel assemblies.

b. Barrel halves.—The barrel halves are supported on the spider by means of phenolic blocks located between the spider arms, and are held together by means of barrel bolts. Shoulders machined in the barrel take up the centrifugal load from the blades.

c. Blades.—The conventional hydromatic propeller blades are identical in basic design with those of the Hamilton counterweight



① Blade assembly.



② Attachment of blade gear to blade bushing.

FIGURE 49.—Blade assembly, and attachment of blade gear.

type controllable propeller. However, they differ slightly at the inner end, and are not interchangeable with the other type of blades. "Paddle" blades have been designed for use with the hydromatic propeller. These blades have approximately the same chord throughout their length, and the airfoil is carried up to the barrel. They provide greater power absorption from the same diameter propeller, and provide better cooling for radial engines. Both types of hydromatic blades are manufactured from high-strength aluminum-alloy forgings and are of semihollow construction. A shoulder is machined on the blade butt to carry the centrifugal load (fig. 49①).

(1) *Thrust-bearing assembly.*—The blade thrust-bearing assembly consists of two thrust races which are not removable from the blade, and a split bearing retainer between the races. The centrifugal blade loads are transmitted from the shoulder on the blade butt to the inner, or beveled, thrust race. The outer or flat thrust race transmits the bearing loads to the "lips" of the barrel halves. The roller thrust bearings in the bearing retainer are designed for low friction under high loads.

(2) *Blade bushing and spring packs.*—Blade bushings, made of aluminum-bronze alloy, are shrunk into the tapered holes in the blade ends and secured by two drive pins and two lock screws. Each blade bushing is provided with eight slots, which carry the spring packs for attachment of the blade gear segment (fig. 49②). Each spring pack consists of two spring retainers and approximately 34 spring leaves. The spring packs provide a flexible coupling between the gear segment and the blade bushing. Also, two of the eight spring packs are placed in offset slots (slots not quite opposite) in the bushing and gear segment in order to keep the fit under compression. This tension provides preloading between the blade gear segment and the rotating cam to prevent backlash between the two gears.

d. Dome assembly.—The dome assembly comprises the pitch-changing mechanism of the hydromatic propeller. The assembly consists of four major parts: two cylindrical cams, a double-walled piston, and a dome shell.

(1) *Dome shell.*—The dome shell provides a case for the pitch-changing mechanism and also serves as a spinner. However, its main purpose is to act as a cylinder for the piston of the pitch-changing mechanism. In the forward end of the dome is a breather hole. For engines that have crankcase ventilation through the propeller shaft, a breather tube cup is threaded into this breather hole. For other engines, a dome-seal nut is used. A retaining nut

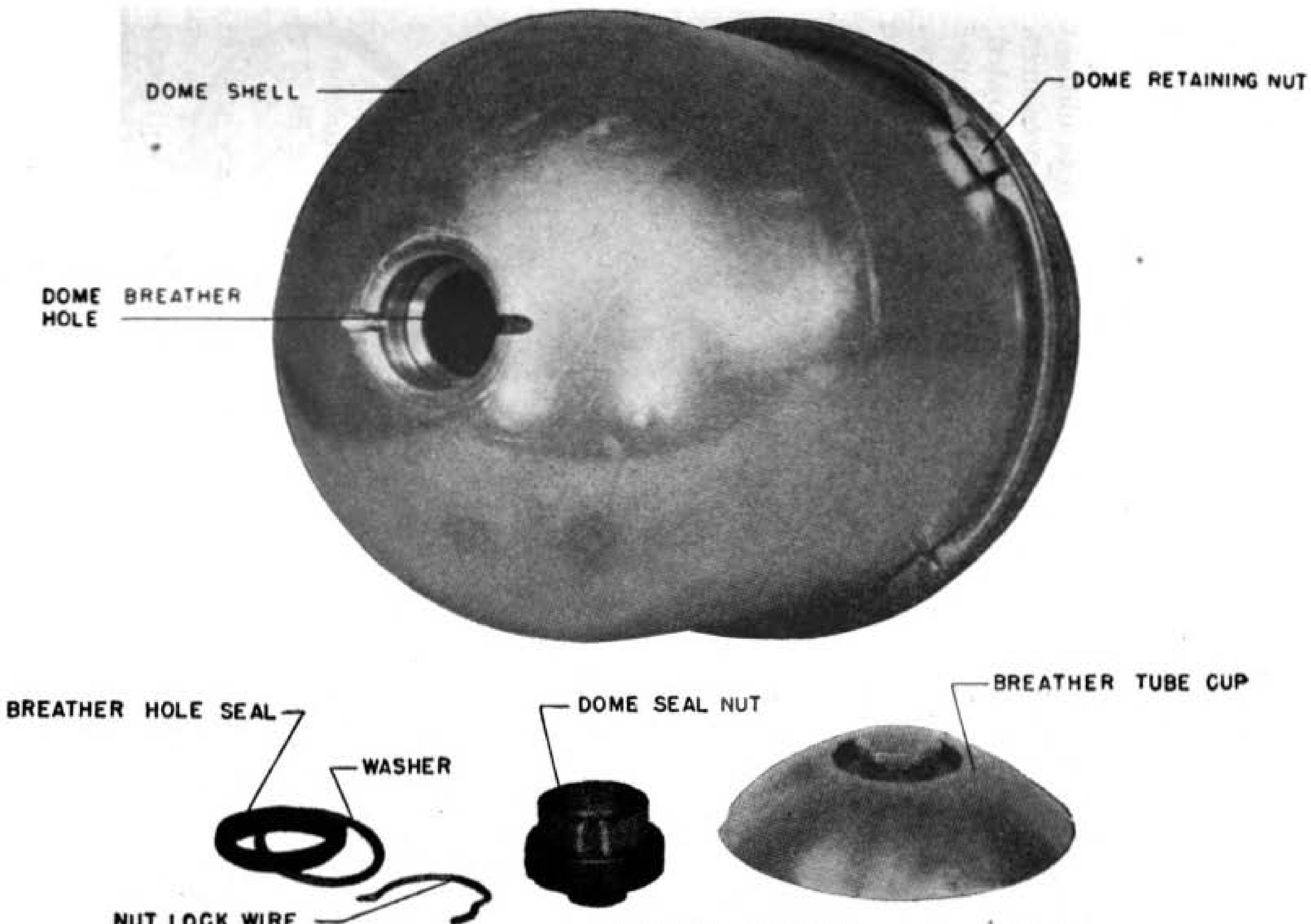


FIGURE 50.—Dome shell and attaching parts.

riding on ball bearings is attached to the inboard end of the dome. The entire dome assembly is readily attached to the propeller by threading this nut into the forward end of the front barrel half (fig. 50).

(2) *Piston.*—The piston is double-walled; that is, it has an inside wall and an outside wall, which are connected at one end but left open at the other (fig. 51). This piston is also double-acting; oil pressure may be directed to either side of the piston, forcing it to move forward or rearward. A large, double-acting piston gasket held firmly in place by means of a ring forms an oiltight seal between the piston and cylinder walls. The two oil pressures, one on either side of the piston, are in this manner kept separated. Two small holes, spaced 180° apart, are drilled through the outer piston wall. These bleed holes circulate a small quantity of warm high-pressure oil from the inboard piston side to the low-pressure

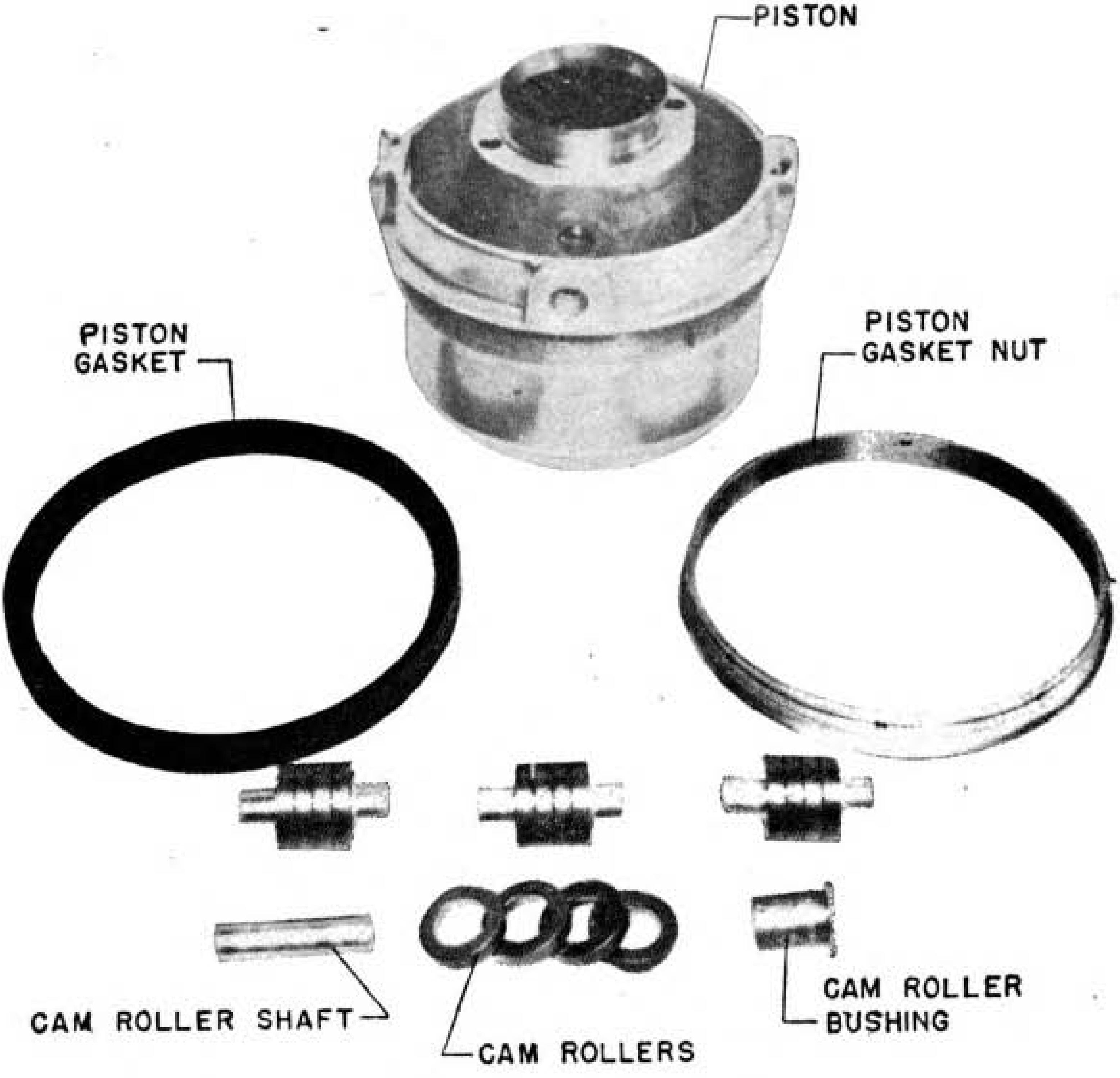


FIGURE 51.—Piston assembly.

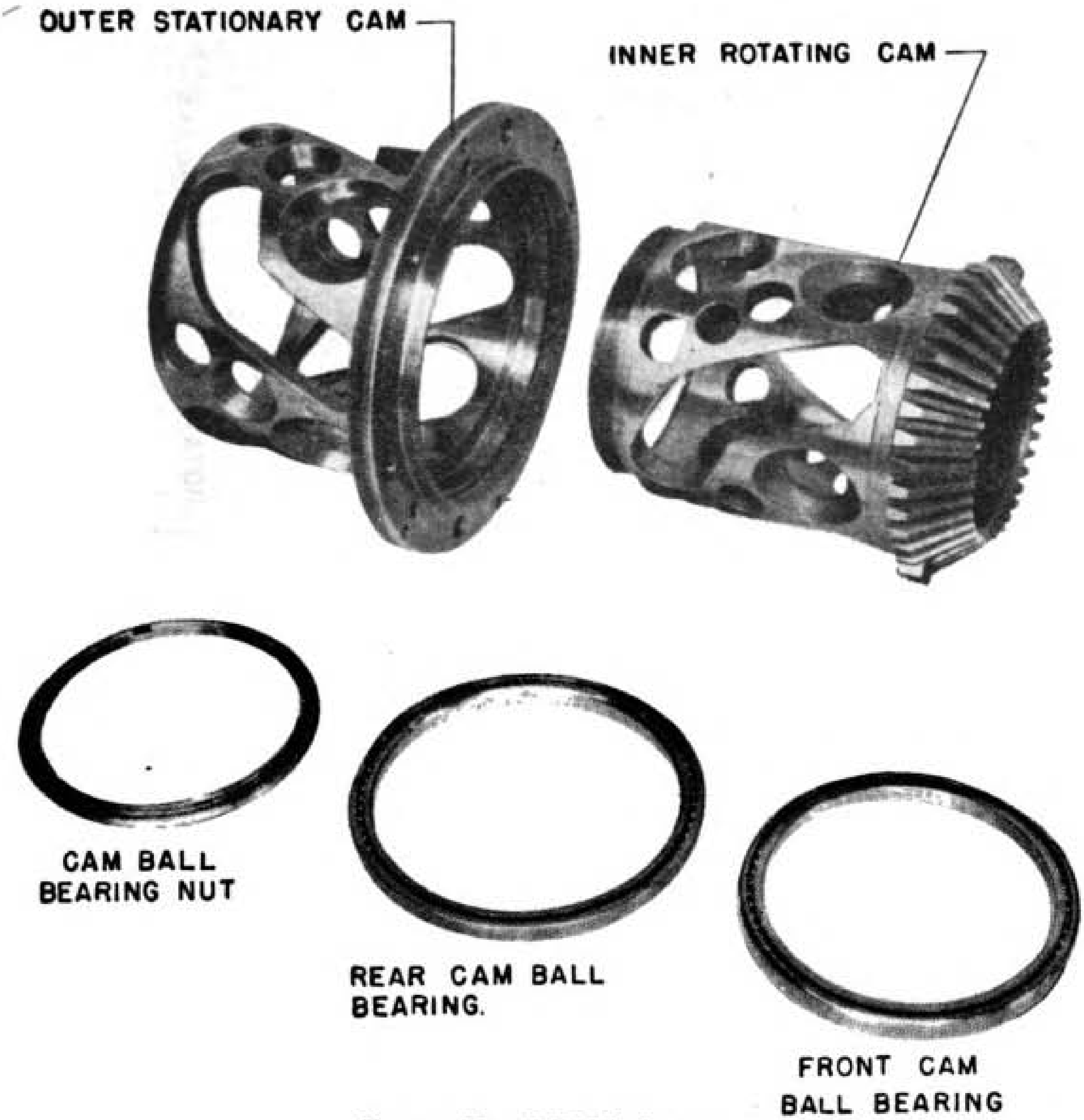


FIGURE 52.—Cylindrical cams.

outboard piston side. Thus, in cold weather and high-altitude operation, ice is prevented from forming on the dome shell, and the oil in the dome shell is prevented from congealing. Extending from the outside to the inside piston walls and attached to them are four steel cam shafts. These shafts, 90° apart, support four sets of steel camrollers operating on bronze bushings. The shafts extend through corresponding slots in the two cylindrical cams, which fit between the inner and outer walls of the piston. The cam shafts and rollers are the means of transmitting the motion of the piston to the rotating cylindrical cam.

(3) *Cams.*—The stationary rotating cylindrical cams are made from steel forgings. The outer or stationary cam is held in the dome shell by means of six screws. Furthermore, when the dome unit is installed in the hub assembly, three dowels on the barrel

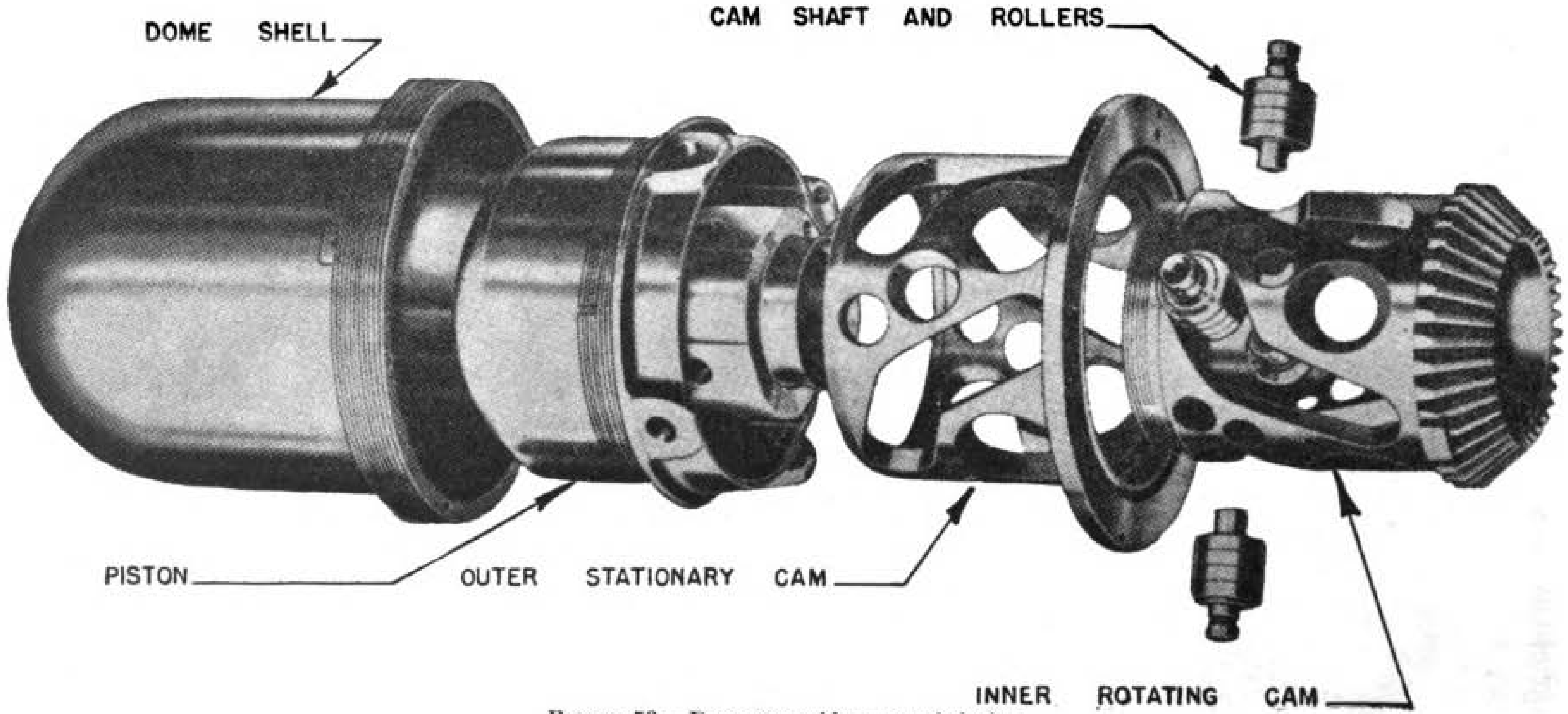


FIGURE 53.—Dome assembly, expanded view.

shelf enter holes in the stationary cam. This cam is thus rigidly fixed in the barrel and provides support for the remaining parts of the dome unit. At the inboard end of the inner rotating cam, and integral with it, is a bevel gear which engages the gear segments attached to the blade butts. The rotating cam is supported within the stationary cam by means of ball bearings (fig. 52). Three different types of rotating and stationary cams are used in the hydromatic propellers: standard cams (shown in fig. 52); fast-acting cams (which have steeper slopes than the standard cams); and straight-slope cams. The latter are used in nonfeathering hydromatic propellers.

(4) *Cam slots.*—Each cam has four slots, spaced 90° apart. The slots of the rotating cam slope in the opposite direction from those of the stationary cam, as shown in figure 52. (The circular cut-outs in the cams are for the purpose of making them lighter.) Through the action of the cam shafts and rollers in the cam slots, the linear motion of the piston results in rotary motion of the inner rotating cam (fig. 53). Rotation of the gear integral with this cam, when engaged with the blade gear segments, causes the blades to turn. To illustrate, assume that the piston is in a position as indicated in figure 54①. When the piston is moved forward by oil pressure which is higher on the inboard side than on the outboard side, the cam shafts and rollers must follow the slots in the outer cam, which is held stationary and rigid to the dome and barrel. On the other hand, the slots of the inner cam, which is free to rotate, must "follow" the cam shafts and rollers. If the higher oil pressure on the inboard side is continued long enough, the position indicated in figure 54② will be reached. This movement of the piston, cam shafts, and rollers causes sufficient motion of the inner cam, whose integral gear meshes with the blade gear segments, to turn the blades approximately 35°. This is the maximum blade-angle range required in normal flight. The position indicated in figure 54① is full-low pitch, and the position indicated in figure 54② is the highest pitch for normal constant-speed operation. To feather the propeller, the cam shafts and rollers must be forced up the steeper slope of the slot. To accomplish this movement, a still higher oil pressure is required on the inboard end of the piston. This pressure is supplied by the auxiliary oil system of the propeller. The position indicated in figure 54③ is then reached. A high oil pressure on the outboard end of the piston will unfeather the propeller by moving the piston rearward, so that the cam shafts and rollers move from the position shown in figure 54③ to the position shown in figure 54② or beyond. During normal pro-

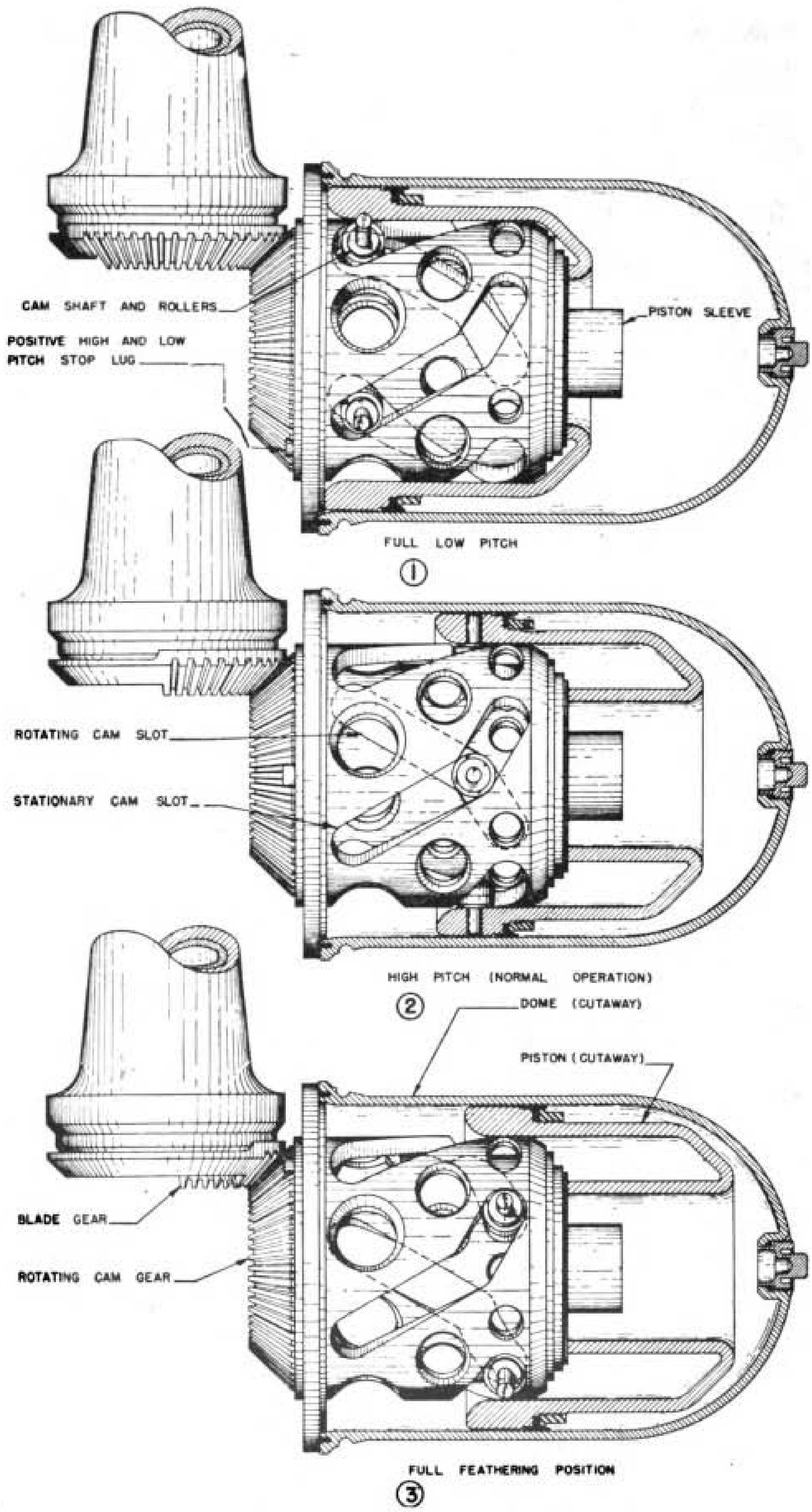


FIGURE 54.—Operation of pitch-changing mechanism.

peller operation, a higher oil pressure on the outboard end of the piston results in movement from the position shown in figure 54② to that shown in figure 54①, causing the blades to move to a lower pitch.

(5) *Stop rings.*—Some means is required to stop the movement of the pitch-changing mechanism when the blades have turned to full-low pitch or to full-high pitch (full-feathered position). The movement is stopped by low- and high-pitch stop rings, and stop lugs which are built integrally with the rotating cam. The stationary cam has a series of fine teeth which mesh with similar teeth on the outside diameter of the two stop rings. These stop rings are assembled one on top of the other in the stationary cam (fig. 55). The rotating cam movement is limited to the desired range by adjusting the position of the stop rings in the stationary cam. When the stop rings are properly assembled, the two stop lugs (180° apart) on the rotating cam will strike the two stops (180° apart) on the high-pitch stop ring when the propeller blades are in the full-feathered position. Likewise, when the propeller blades

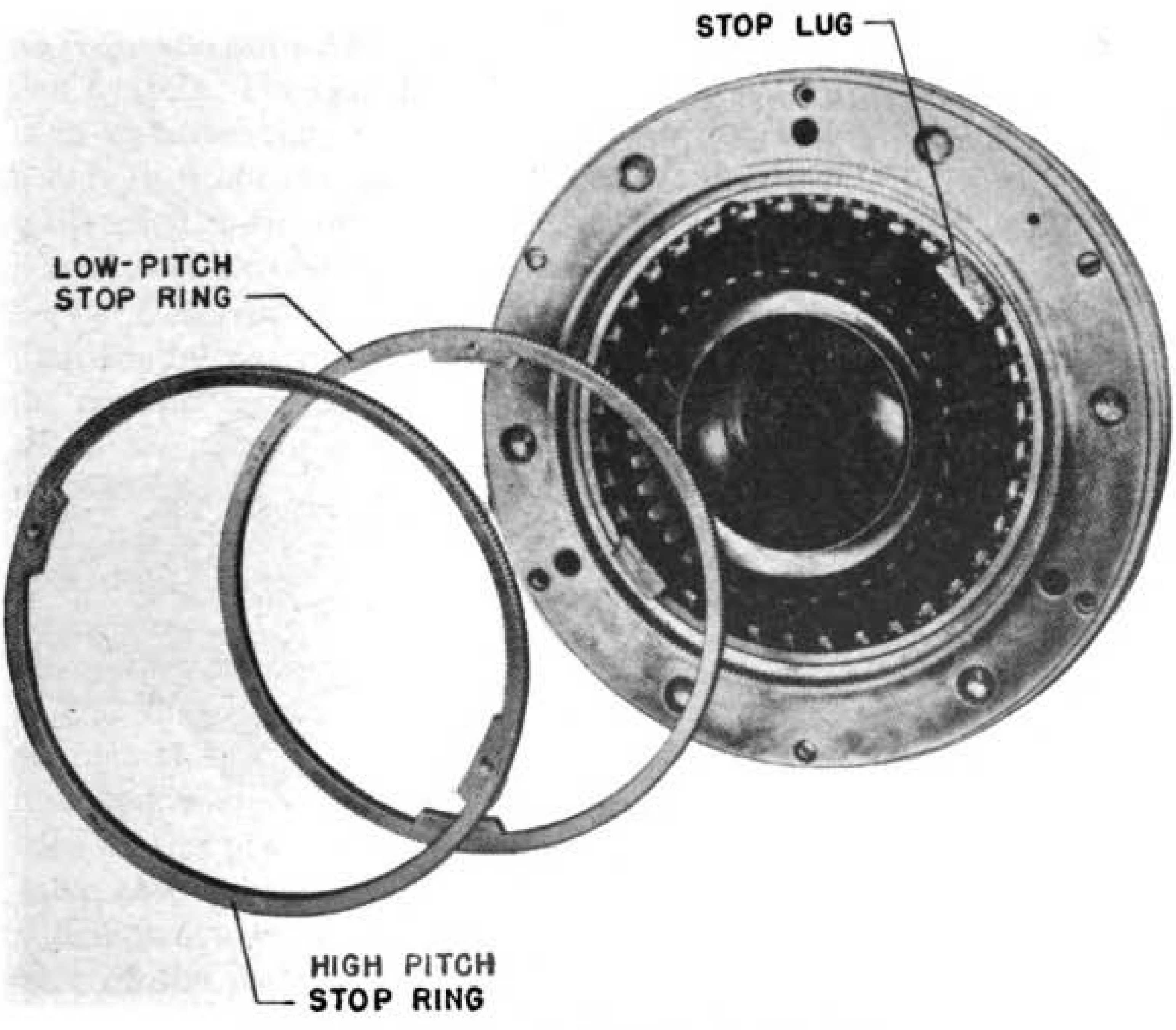
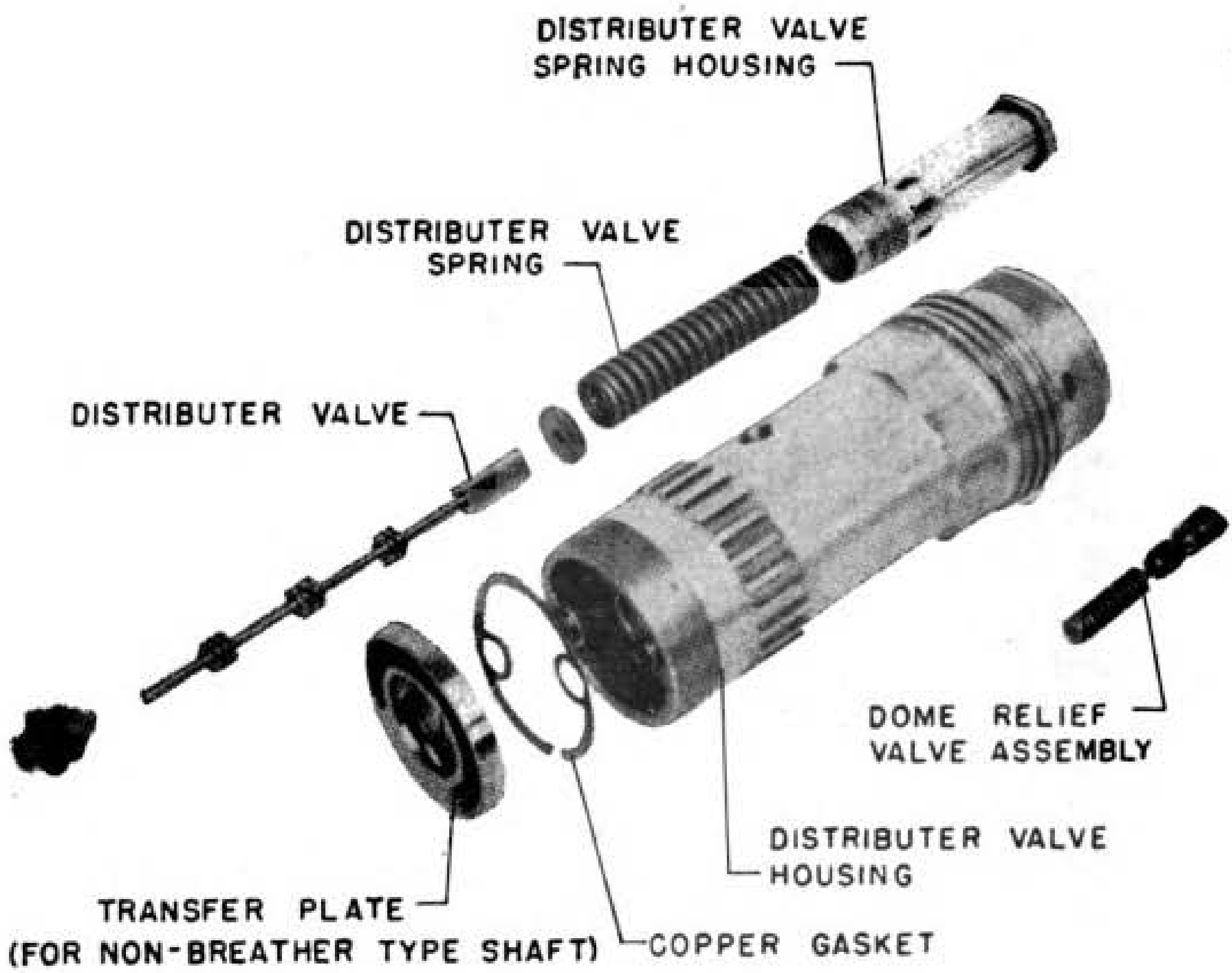
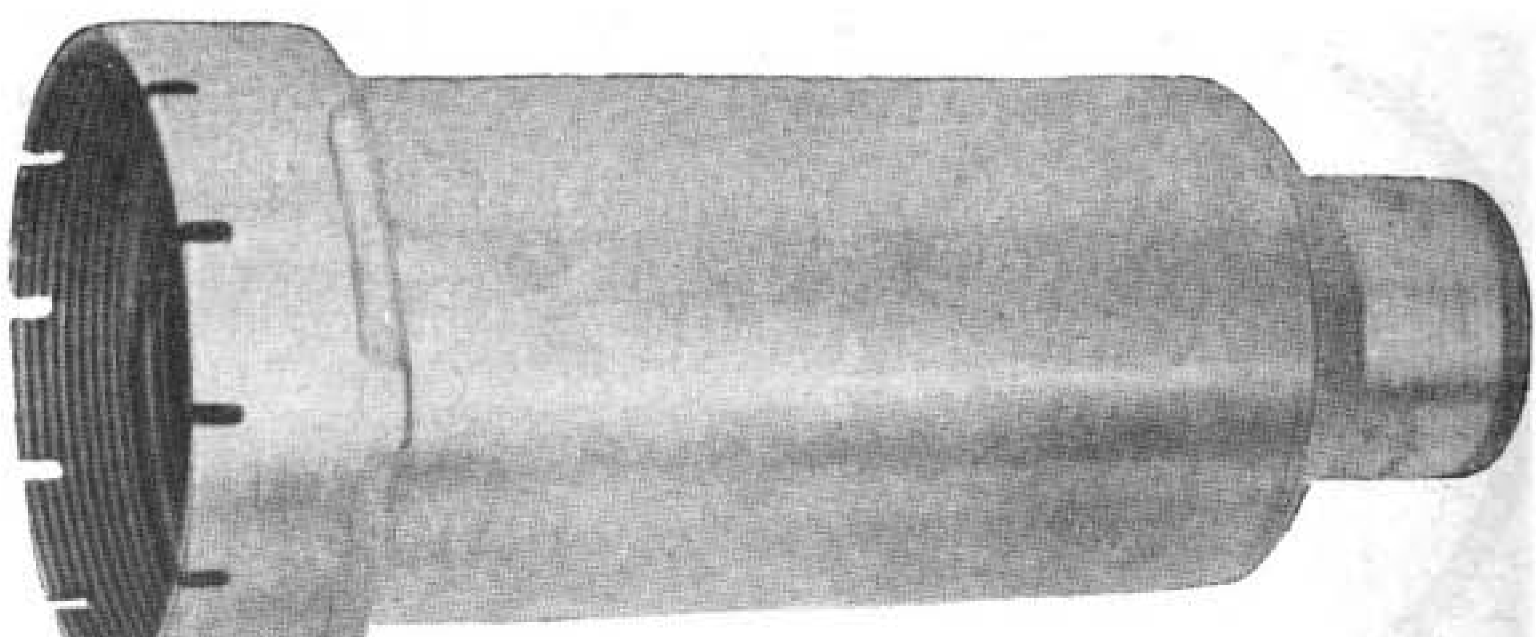


FIGURE 55.—Low- and high-pitch stop rings.



① Assembly, nonbreather installation.



② Dome breather tube (used in breather installation).

FIGURE 56.—Distributor-valve assembly.

have turned to the desired low-pitch setting, the stop lugs on the rotating cam will strike the stops on the low-pitch stop ring. The oil pressure which moves the blades to a higher angle in normal-flight operation is not sufficient to move the cam shafts and rollers up the steeper slope of the cam slots. The "hump" in the cam slots is therefore the stop for the high blade required in normal flight.

e. Distributor-valve assembly.—Oil under pressure is directed to both the outboard and the inboard sides of the piston. However, a separate oil supply for each side comes through the propeller shaft from different sources, and under different pressures. One function of the distributor-valve assembly is to provide oil passages to carry engine oil and governor oil from the end of the propeller shaft to the proper sides of the piston. The oil passages of this assembly direct engine oil under normal pressure to the outboard side of the piston, and engine oil under boosted pressure from the governor to the inboard side of the piston. During the feathering operation the same two passages provide means for delivering high-pressure oil from the auxiliary oil system to the inboard side of the piston and also provide a means of conducting oil from the outboard side of the piston back to the engine lubrication system. The other function of the distributor-valve assembly is to reverse the same two passages for unfeathering the propeller. In this case, high-pressure oil from the auxiliary oil system is directed to the outboard side of the piston, and the inboard side is connected with the engine lubrication system.

(1) *Description.*—The distributor-valve housing is provided with the oil passages mentioned above. A steel sleeve, shrunk into the central bore of the housing, contains ports which align with oil passages in the housing. The distributor valve operates in this sleeve. Its forward end rests against the distributor-valve spring. A transfer plate is fitted to the rear end of the distributor-valve assembly. The purpose of this plate is to collect the oil from the propeller-shaft adapter line and direct it to smaller ports in the distributor-valve assembly (fig. 56①). The valve assembly threads to the inside of the propeller shaft, the transfer plate resting against the propeller-shaft adapter. When the dome assembly is installed, a steel sleeve pressed permanently in place in the inner bore of the piston slides over the distributor-valve assembly. The valve assembly is equipped on its outboard end with oil-seal rings which provide a seal between the valve assembly and the inner bore of the piston, keeping the engine oil and governor oil separated. An additional passage is cored in the housing to carry off the oil fumes of propellers that have crankcase ventilation through

the propeller shaft. A breather tube is screwed on the front end of the housing to carry the oil fumes to the dome breather hole (fig. 56②).

(2) *Operation.*—In normal operation, one passage in the distributor-valve assembly carries engine oil to the outboard side of the piston; the other directs governor oil to the inboard side of the piston (fig. 57). In the feathering operation, high-pressure oil from the auxiliary system flows through the same passages that normally conduct governor oil to the inboard side of the piston. During this operation, the governor oil supply is cut off. Engine oil on the outboard side is forced back into the engine lubrication system. In the unfeathering operation, the auxiliary oil system continues to build up the pressure on the inboard side of the piston —which has gone the extent of its forward travel—until the pressure on the distributor valve causes it to compress the distributor-valve spring. This movement of the distributor valve realigns the ports, so that the high-pressure oil is directed to the outboard side of the piston to unfeather the propeller. The inboard side of the piston is then connected to the engine lubrication system. A dome pressure-relief valve (or a dump port in newer models) is provided in the distributor-valve assembly to prevent excessive oil pressure on the outboard side of the piston during unfeathering (fig. 57).

35. Hydromatic propeller governor.—*a.*—*Description.*—(1) The

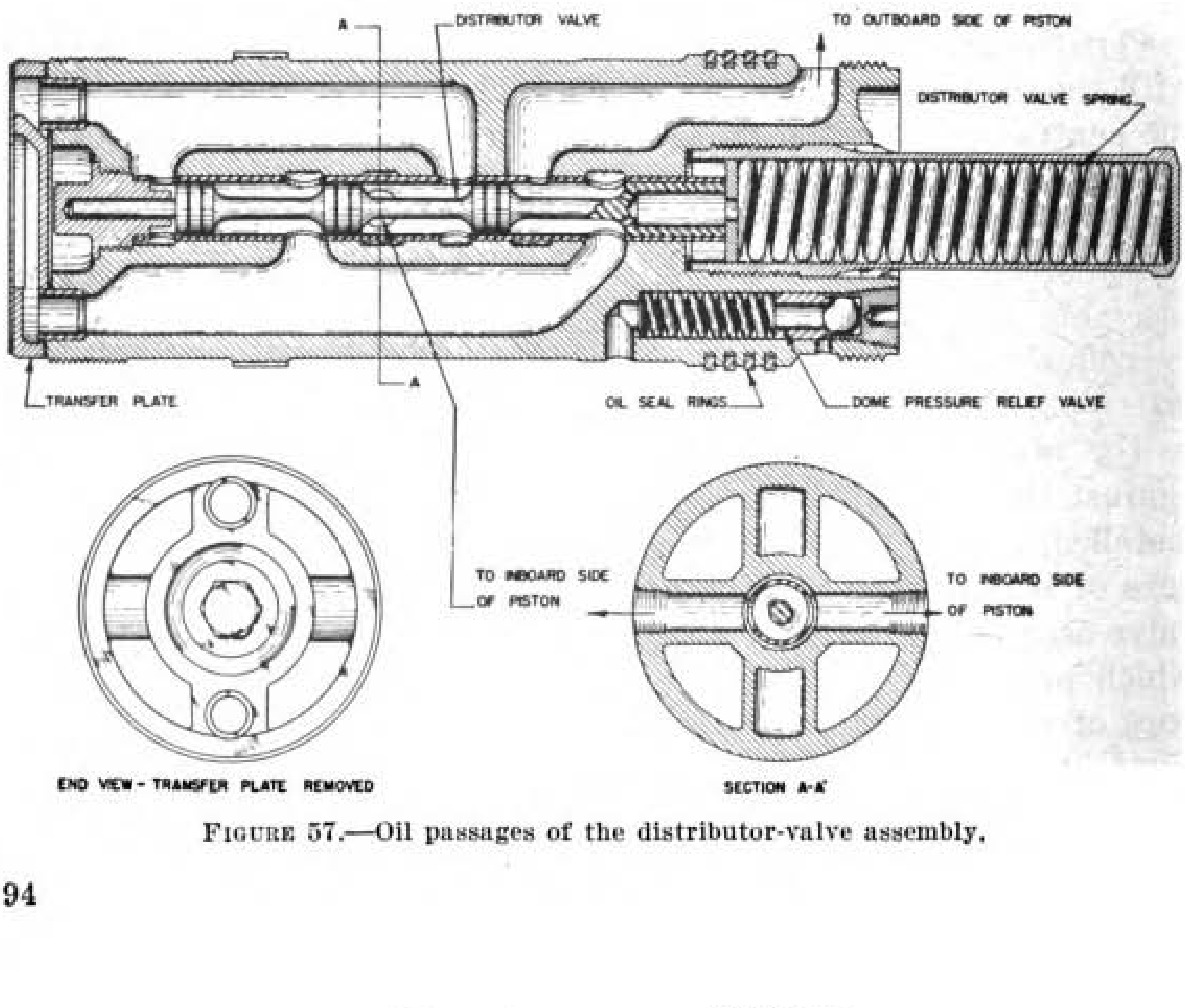


FIGURE 57.—Oil passages of the distributor-valve assembly.

Hamilton standard hydromatic propeller governor is similar to the Hamilton standard constant-speed propeller governor in construction and principle of operation (see par. 27). These two governors differ, however, in actual operation. Due to differences in construction and operation of the pitch-changing mechanisms, oil under pressure supplied by the constant-speed propeller governor moves the blade of that propeller to a lower pitch, whereas the oil under pressure supplied by the hydromatic propeller governor moves the blades of that propeller to a higher pitch. Hence, the oil ports which are opened and closed by the governor flyweight valve must be positioned differently in the two governors.

(2) The hydromatic propeller governor is suitable for mounting on the special built-in pad on the nose of the engine. The principal parts of this governor are the base, the body, and the cover (fig. 58).

(3) Mounted in the body of the governor is the hollow spindle shaft, which is splined at its lower end to fit a standard governor drive shaft from the engine. The spindle shaft drives the gear pump and the flyweight assembly, and has ports that open to the high-pressure line and the propeller line. The governor oil pressure is limited by a relief valve, the kick-out pressure of which may be found in the applicable Technical Order. This valve requires adjustment only at overhaul periods. Two flyweights and a flyweight cup are mounted on the upper end of the spindle shaft. The speeder spring bears on the flyweight valve, which is mounted so that it will move in response to changes in the two opposing forces in the governor. The valve slides in the spindle shaft, opening and closing the oil ports in that shaft.

(4) The governor cockpit control is connected by means of cables to the governor pulley, which is fitted to the outer end of the governor control shaft. The inner end of this shaft has a gear whose teeth mesh with teeth on the face of the governor rack. Any movement of the cockpit control will rotate the governor pulley and control shaft, and cause the control-shaft gear to move the rack up or down. The rack bears on the upper end of the speeder spring, so that its up and down movements will vary the compression of the spring. A stop for the high limit of the governing range of the unit is provided on the control pulley. It consists of a pin that can be located in any one of a number of holes in the pulley. The motion of the pulley is stopped when the pin contacts the adjustable screw which is threaded through a mount integral with the cover. The governor cut-off valve and, on some models, the pressure cut-out switch of the auxiliary oil system for the feather-

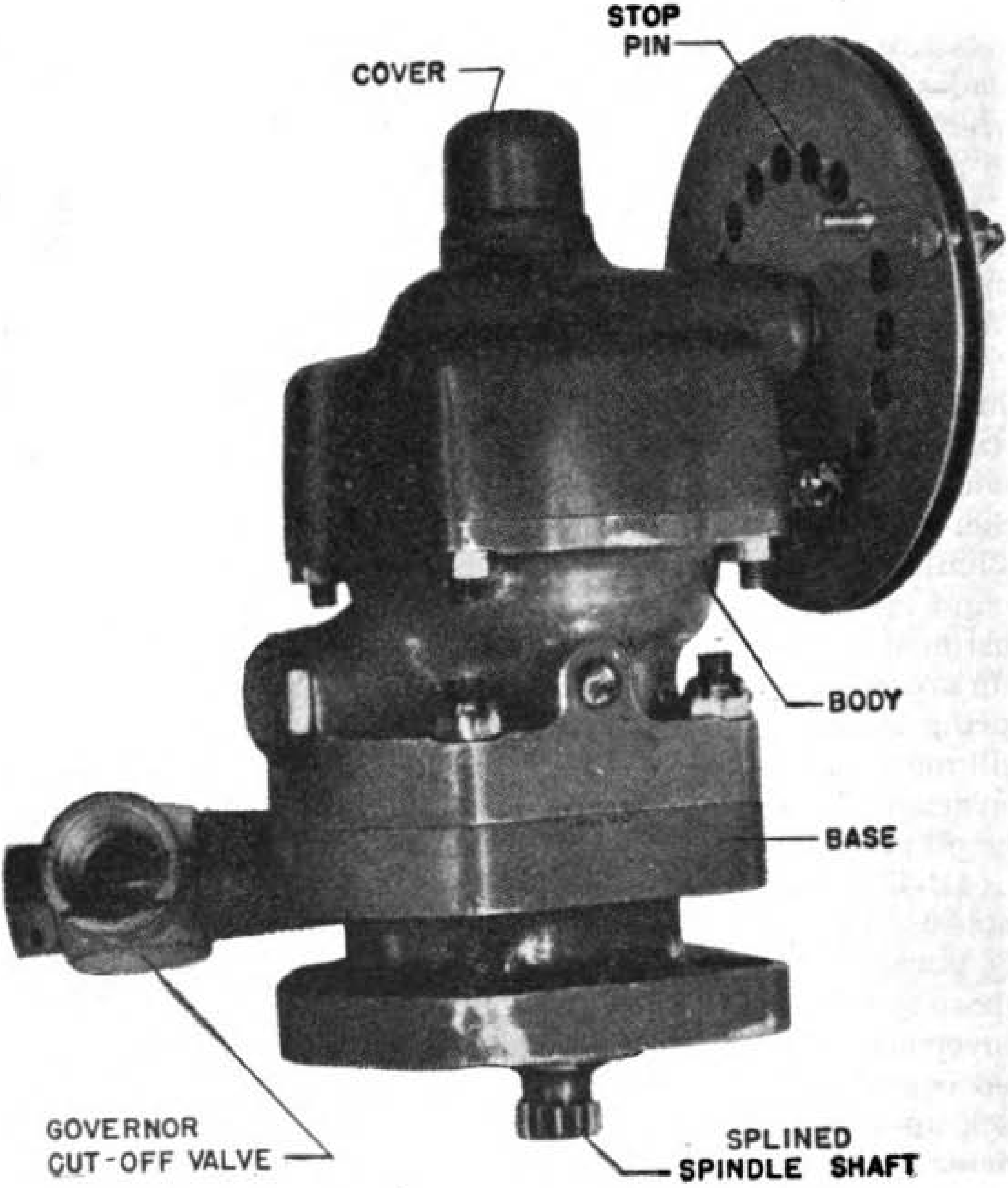


FIGURE 58.—Hydromatic propeller governor.

ing and unfeathering operations, are located on the governor base. A gasket between the cover and body sections, and another between the body and base sections to prevent oil leakage, complete the governor assembly.

(5) The double-capacity-model governor was designed for use with the fast-acting type cams and with certain blade designs, such as paddle blades and extra long blades, which have a higher centrifugal twisting moment than can be controlled by the standard governor. The additional oil pressure and volume produced by this governor provide additional force and output to meet the requirements for a higher rate of pitch change for propeller installations. The general operating principles are the same as those of the hydromatic governor previously described. However, the double-capacity governor incorporates a higher-capacity booster pump, and a pressure-relief system which relieves the pump when governor oil pressure is not required for pitch change. As a result of this relief system, a very low power input to the governor drive is needed whenever governor oil pressure is not required for pitch change. The only adjustment on the relief system is made on the high-pressure relief (dump) valve. The adjusting screw is found in the governor base at the parting line between the base and the engine pad. A pressure gauge should be installed in the governor outlet line, and the dump-valve screw so adjusted that the gauge will indicate the value given in Technical Orders *plus normal engine oil pressure,* inasmuch as engine oil pressure aids in keeping the valve closed.

b. Principle of operation.—(1) When the centrifugal force on the flyweights exactly balances the force on the speeder spring, the flyweight valve will be in such a position that it will close off the ports to the propeller line. Oil cannot flow either to or from the propeller cylinder, so that the pitch of the blade is held fixed (fig. 59). The output of the booster pump is bypassed through the relief valve to the inlet side of the pump. If the engine speed decreases, the speed of rotation of the flyweights will decrease with the decreasing engine rpm. This decrease will cause a reduced centrifugal force on the flyweights, and this will permit the speeder spring to override the flyweights. The flyweights will therefore move inward and the flyweight valve downward. The ports are so positioned in the governor that the downward movement of the valve will open the propeller line to the drain. When the oil drains from the inboard side of the piston of the hydromatic propeller, engine oil pressure on the outboard side plus the low-pitch tendency of the blades turns the blades to a lower pitch.

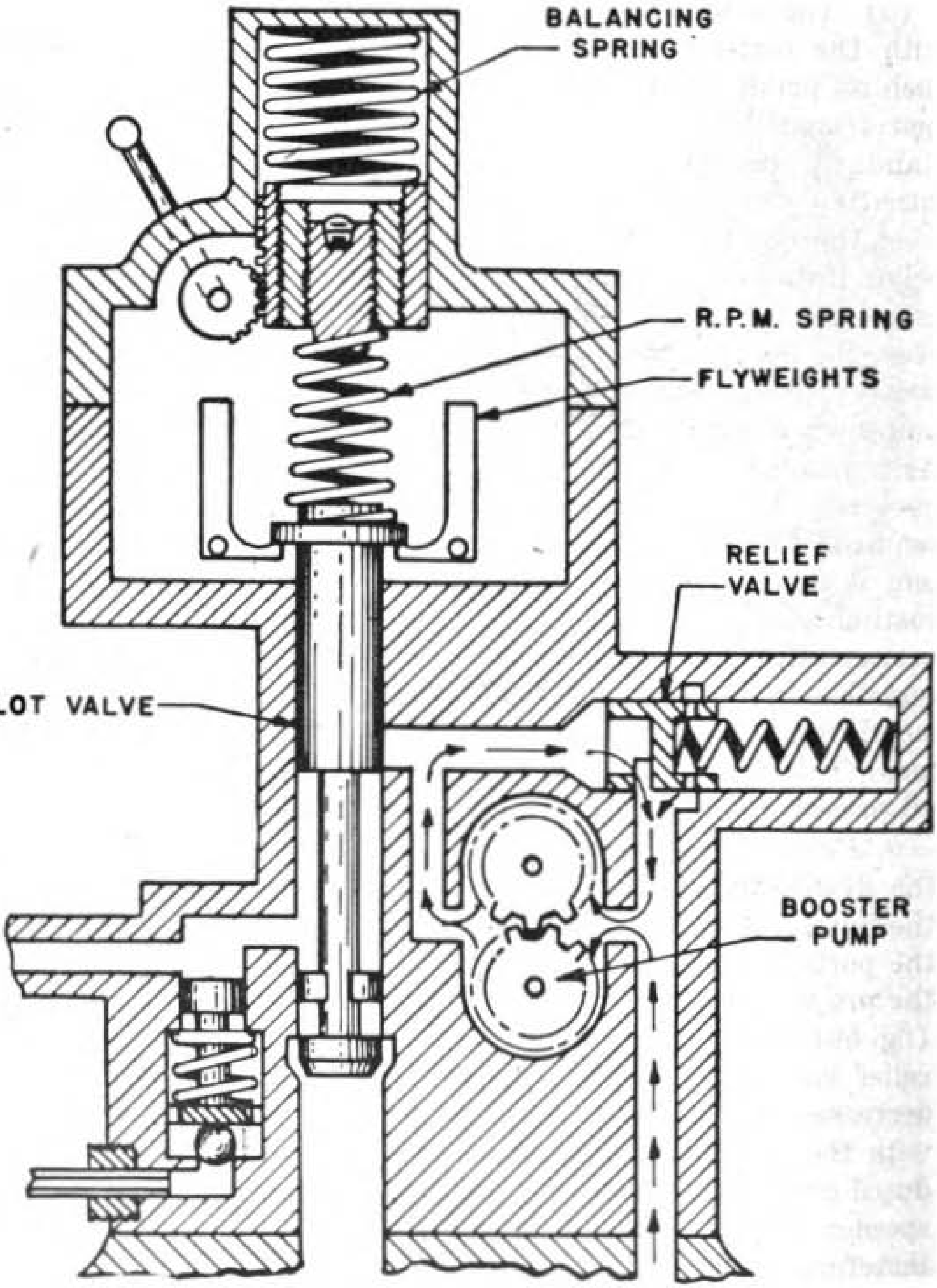


FIGURE 59.—Schematic diagram of the hydromatic propeller governor.

This lower pitch permits the engine speed to return to the original rpm, and the flyweights and speeder spring in the governor return to a balanced, "on speed" condition. If the engine speed increases, the flyweight force exceeds the force of the speeder spring. The flyweight valve is raised, opening the governor oil line to the propeller line and closing the drain. Governor oil pressure is directed against the inboard end of the propeller piston, and the blade angle is increased. The engine speed is thus reduced, and the flyweights and the speeder spring return to a balanced "on speed" condition.

(2) In the feathering and unfeathering operations of the hydromatic propeller, oil under pressure from the propeller auxiliary oil system passes through the cut-off valve located in the governor base. The operation of this valve cuts off the governor oil from the propeller line and permits the auxiliary oil to enter it. If the propeller will not feather or unfeather or is sluggish in these operations, the difficulty may often be traced to a defective cut-off valve. If this valve leaks, it will permit oil to drain through the governor into the engine lubrication system. This will affect the operation of the propeller pitch-changing mechanism during feathering and unfeathering.

c. Electric-head governors.—(1) Some models of the Hamilton standard hydromatic propeller governors have electric heads which replace the mechanical heads of the other models. The only difference is in the heads and the different means of rpm control which they supply. The electrically controlled governor is mounted on the standard pad on the nose of the engine in exactly the same manner as the mechanically controlled governor. The electric-head governor is electrically controlled from the cockpit, the connection being electric wiring instead of the push-pull rods and cables used in mechanical installations.

(2) Electric-head governors that will operate on 12- or 24-volt systems have been designed. The cockpit control is a spring-loaded, toggle-type switch with three positions: OFF, INCREASE RPM, and DECREASE RPM. If this switch is thrown from the center (OFF) position to either the Increase-rpm or decrease-rpm position, the electrical circuit to the electric head of the governor is completed. The electrical current passes through one field of a reversible d-c motor in the electric head and at the same time energizes a solenoid that operates a dog clutch. As the motor begins to rotate, the solenoid-operated clutch engages the armature shaft with a set of reduction gears that operate the screw-shaft spring-compressing gear. The screw shaft is a gear of the worm type,

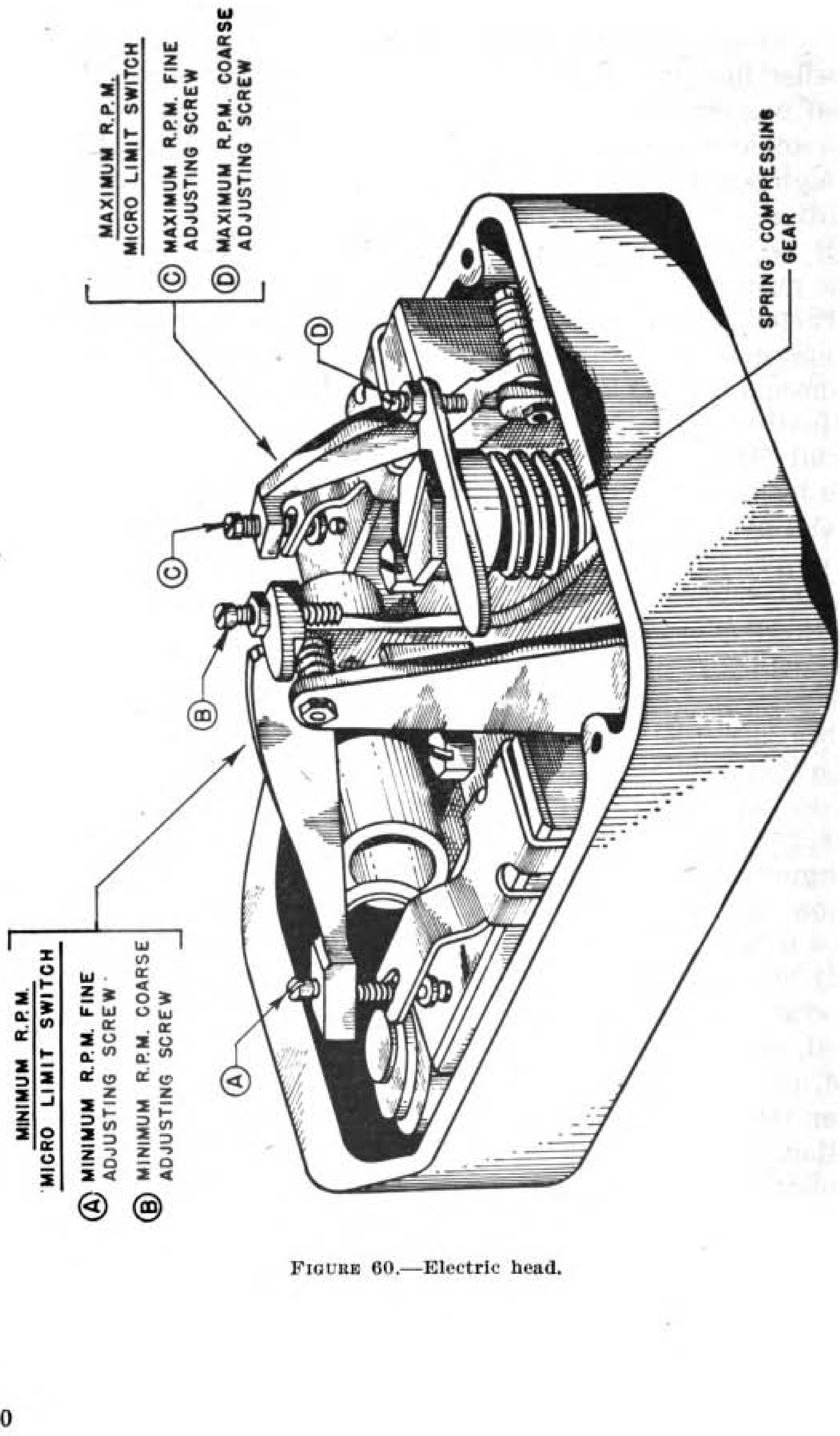


FIGURE 60.—Electric head.

and one end bears against the governor-speeder spring. If the increase-rpm circuit is completed, the electric motor will rotate in such a direction that the reduction gears will operate to move the spring-compressing gear down. The compression of the speeder spring will be increased, causing an increase in engine rpm. On the other hand, if the cockpit switch is placed in the decrease-rpm position, the electric circuit will be completed to the other field of the reversible motor. The electric motor will then rotate in the opposite direction so that the reduction gears will operate to move the spring-compressing gear up. The compression of the speeder spring will be decreased, and a decrease in engine rpm will result. Since the control switch is spring-loaded, it will return to the OFF position the moment it is released. The solenoid-operated clutch will then disengage the armature shaft from the reduction gears. A brake arrangement will stop the movement of the spring-compressing gear almost immediately.

(3) The electric-head governor is provided with two limiting micro-switches. When the spring-compressing gear has moved up or down to the limit of its travel, one or the other of these switches opens the motor and solenoid circuit and closes the circuit to an indicating lamp on the cockpit control switch. Thus, when the indicating lamp lights, the pilot knows that the maximum or minimum rpm setting has been reached. Adjusting screws are incorporated with the micro switches and spring-compressing gear to provide for readjustment of the maximum and minimum rpm settings (fig. 60).

36. Principle of operation.—*a. Control of blade angle.*—Three forces are used to control the blade angle during constant-speed operation. One of these forces is the centrifugal twisting moment of the blades, which tends to cause the blades to turn toward low pitch. Because this force is not very great at low propeller speeds, a second force, engine oil under normal pressure from the engine lubrication system, is used to supplement the natural low-pitch tendency of the rotating propeller. The third force is engine oil under boosted pressure from the governor. This force, tending to move the blades toward high pitch, opposes the other two forces. For the feathering and unfeathering operations, higher oil pressures are required and an independent auxiliary oil system is therefore included as a part of the propeller control system. Frequent reference should be made to figure 61 during the following discussion.

(1) *Engine oil.*—Engine oil is directed from the engine lubrication system to a collector ring on the propeller shaft. This ring

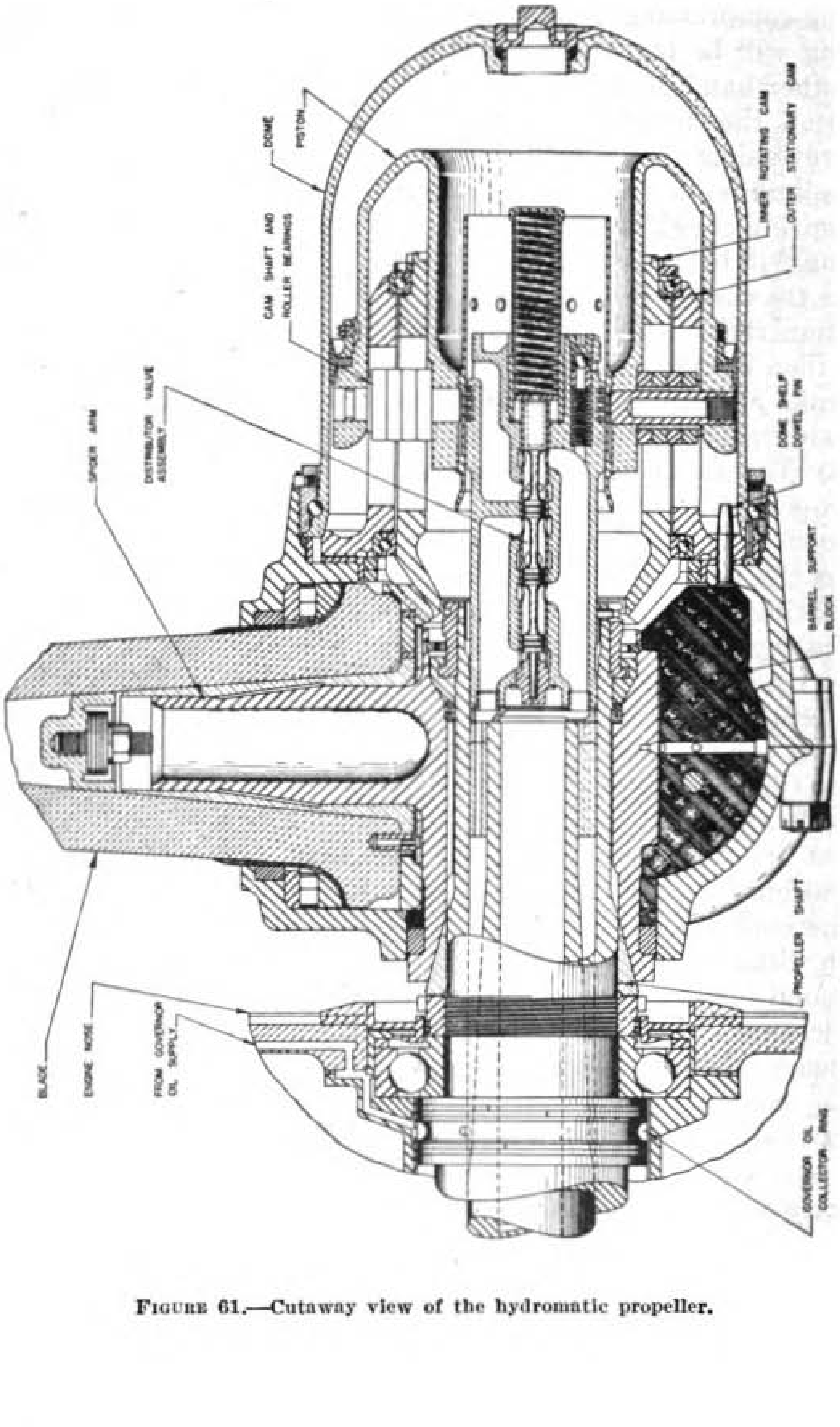


FIGURE 61.—Cutaway view of the hydromatic propeller.

transfers the oil into the shaft adapter. The transfer plate, attached to the distributor valve and installed against the propeller-shaft adapter, collects the oil at the end of the shaft and conducts it to a passage in the distributor-valve housing assembly. The oil flows through this passage to the outboard side of the piston, and fills this side with engine oil, exerting a pressure at all times during normal constant-speed operation.

(2) *Governor oil.*—Engine oil is also directed to the governor. A governor pump produces a higher pressure. The value of this pressure (above engine oil pressure) depends upon the type of governor, and may be found in Technical Orders. The governor oil is then metered by the governor to another collector ring on the propeller shaft, and this ring transmits the oil into the propeller shaft, around the outside of the adapter which carries the engine oil. Another groove in the transfer plate collects the governor oil and directs it into the corresponding passage of the distributor valve. The governor oil flows through this passage to the inboard side of the piston; it is also inboard of the oil-seal rings and piston gasket. Thus the piston gasket keeps the governor oil separated from the engine oil between the outer piston wall and the cylinder, while the oil-seal rings keep these two pressures separated through the inner bore of the piston. Governor oil also fills the entire propeller assembly, flowing to the rear of the barrel and around the shanks of the blades, providing the necessary internal lubrication for the propeller assembly. Oil seals are provided to make the propeller assembly oiltight (see par. 40*b*).

(3) *Auxiliary pressure systems.*—The auxiliary pressure system provides high-pressure oil for feathering and unfeathering Hamilton standard hydromatic propellers. It contains an electric motor-driven pump which supplies oil from the engine tank to the propeller. When the system is put into operation, oil under high pressure is supplied through the governor line to the propeller pitch-changing mechanism, the governor being automatically disconnected from the system. For feathering, the oil goes to the inboard side of the piston; for unfeathering, movement of the distributor valve realigns the ports in the distributor-valve housing and directs the oil to the outboard side of the piston.

b. Examples of constant-speed operation.—By admitting oil to, or allowing it to drain from, the inboard end of the cylinder in the required quantity and thus producing the required oil pressure, the governor is able to maintain the blade angle necessary for constant-speed operation.

(1) If the engine is rotating at the speed which the pilot has

selected by means of the cockpit governor control—in other words, if the engine is running "on speed"—the forces in the governor are balanced and there is no flow of oil through the governor either to or from the inboard side of the piston, and a constant engine oil pressure is exerted on the outboard side of the piston. The piston does not move, and the blade angle is held constant.

(2) If the engine speed increases above that for which the governor is set, the governor allows oil to flow to the inboard side of the piston. Governor oil pressure is high enough to overcome readily the combined force of centrifugal twisting moment and engine oil pressure. It will therefore move the piston forward. The cam shafts and rollers move in the cam slots, causing the inner cam to rotate. The integral gear or the rotating cam, meshing with the blade gear segments, rotates the blades to a higher angle. The blades take a larger "bite," and the engine slows down to an "on speed" condition. The governor then stops the flow of governor oil and traps a quantity of oil on the inboard side of the piston, holding the blade angle constant.

(3) When the engine speed drops below the rpm for which the governor is set, the flyweight valve is in such a position that it allows governor oil to flow from the inboard side of the piston, through the governor, and drain into the engine sump. Centrifugal twisting moment on the blades and engine oil pressure on the outboard side of the piston become the dominant force, and move the piston rearward. The mechanical linkage of camshafts and rollers, cylindrical cams, and gears translates the rearward movement of the piston into the turning movement of the blades to a lower angle. Since the blades take a smaller "bite," the engine speed increases to the rpm for which the governor is set, and the flow of governor oil from the inboard side of the piston is stopped by the governor, which is again in an "on speed" condition. A quantity of oil is trapped on the inboard side of the piston, and the blade angle is held constant.

(4) During constant-speed operation, the travel of the cam shafts and rollers in the cam slots is limited to the less-steep slope of the slots. This amount of travel allows a change in blade angle of approximately 35°, from full-low pitch to full-high pitch. This blade-angle range is sufficient to allow the governor to maintain the engine at a constant speed (within a few rpm) during all normal airplane operation.

c. Feathering and unfeathering operations.—The feathering and unfeathering operations are described in the paragraphs that

immediately follow. Frequent reference to figures 61 and 62 should be made during this description.

(1) *Feathering.*—When the pilot closes the feathering switch in the cockpit, two electrical circuits are completed through this switch. One is closed from the airplane battery, through the feathering switch to a solenoid switch (*S* in fig. 62) and to an electrical ground. The solenoid switch closes and completes a high-current circuit from the battery to the motor that drives the pump. The other circuit through the feathering switch is closed through the holding solenoid coil of the feathering switch, to the pressure cut-out switch and to an electrical ground. The holding solenoid coil maintains the feathering switch closed without further attention from the pilot. The pump continues to run, supplying oil through the pressure cut-out switch into the line to the governor. The governor cut-off valve operates, disconnecting the governor from the system by closing the governor port. At the same time, the auxiliary oil line is connected to the governor line, which leads to the inboard side of the propeller piston (fig. 62). When auxiliary oil pressure reaches a certain predetermined value (depending on the installation) it will force the piston forward and force the cam shafts and rollers up the steep slope of the cam slots. The inner cam gear will rotate, turning the blades to the full-feathered

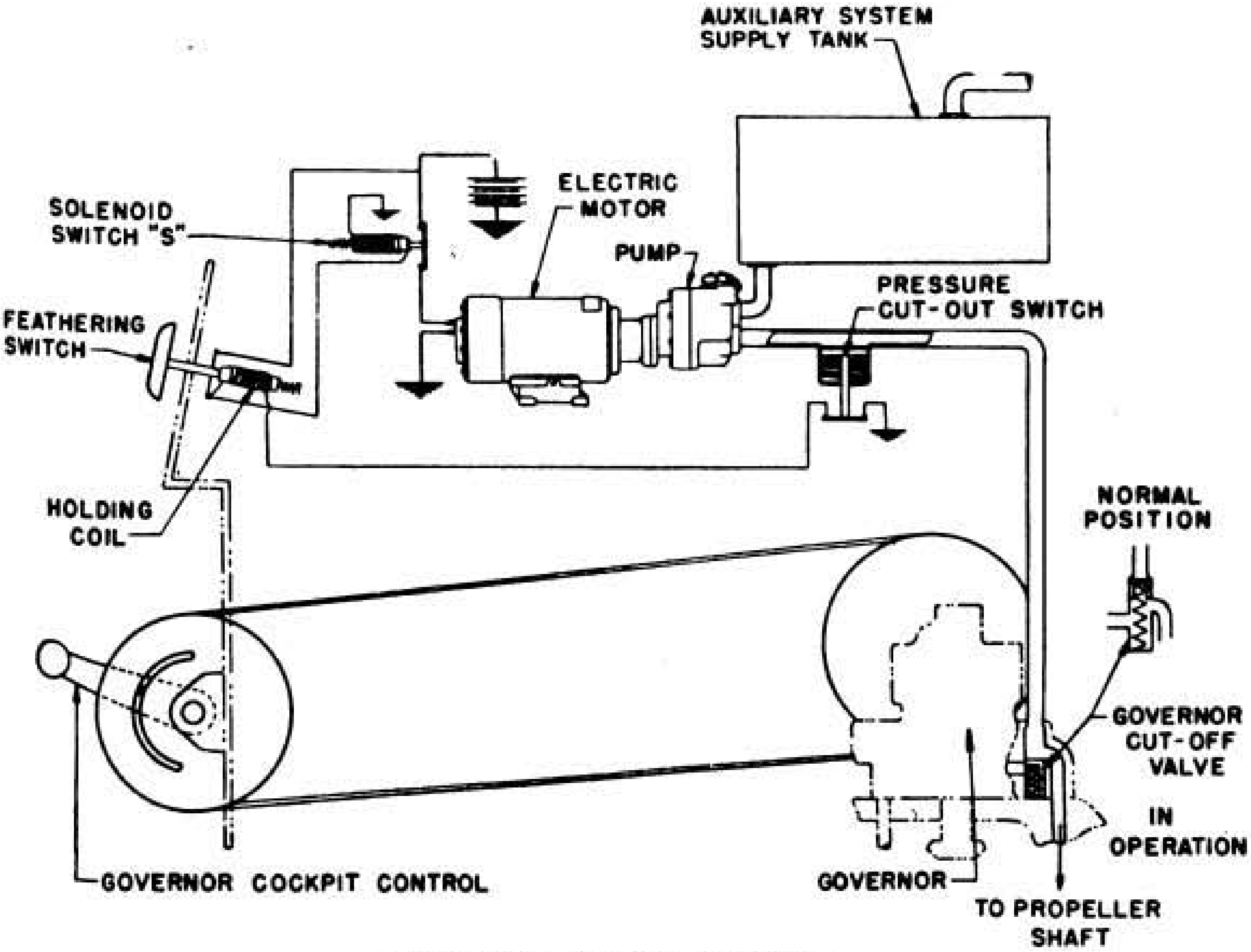


FIGURE 62.—Auxiliary oil system.

position. Oil on the outboard side of the piston is forced back through the passage in the distributor-valve assembly into the engine lubrication system. With the blades in the feathered position, further movement of the mechanism is prevented by the positive high-pitch stops on the rotating cam. The oil pressure now increases rapidly, and upon reaching the correct value for the installation, it opens the pressure cut-out switch. The circuit through the holding coil, from the battery to the electrical ground, is broken, and the coil is no longer energized. As a result, the feathering switch will spring to the OFF position. The other circuit, through the feathering switch to the solenoid switch, is also broken, and a spring returns this switch to the OFF position. The motor circuit is opened and the pump stops. The oil pressure on both sides of the propeller piston drops to zero, and the propeller remains in the feathered position because the forces on either side of the blades balance. It should be noted that the distributor valve does not move during the feathering operation. The valve is spring-loaded, and feathering oil pressure is insufficient to force it to move. The feathering medium then travels to the inboard side of the dome through the normal governor oil passage.

(2) *Unfeathering.*—Unfeathering the propeller consists essentially of reversing the alignment of the passages and ports in the distributor-valve assembly. The high-pressure oil from the auxiliary system is thus permitted to act on the outboard side of the piston, while the inboard side is connected to the engine lubrication system. To unfeather the propeller, the pilot closes the feathering switch, *and holds it closed,* until the propeller is unfeathered to the desired rpm. The motor-pump circuit is completed in exactly the same manner as during the feathering operation. Oil under high pressure from the auxiliary system is again delivered to the inboard side of the piston. Since the piston is at its outermost position, the oil pressure rapidly increases. When this pressure becomes great enough, the pressure cut-out switch opens and deenergizes the holding coil. This, however, does not break the pump circuit, since the pilot continues to hold the feathering switch closed, so that the circuit to the solenoid switch is not broken. As the pressure continues to increase, the distributor valve moves outward, compressing the distributor-valve spring. The pressure soon becomes great enough to move the valve completely forward, so that the ports and passages are realigned (fig. 61). High-pressure oil from the auxiliary system is directed to the outboard side of the piston, and the inboard side of the piston is connected to the engine lubrication system. As the piston

is forced rearward, the cam shafts and rollers move in the cam slots, and the rotating cam unfeathers the blades. As the blades are unfeathered, they begin to windmill, and unfeathering is assisted by the centrifugal twisting moment. When the engine has reached the desired rpm (800), the feathering switch is released. This discontinues the flow of high-pressure oil from the pump and allows the distributor valve and the governor cut-off valve to return to their normal constant-speed positions. The governor is again connected with the inboard end of the cylinder, and constant-speed operation is automatically resumed at the rpm for which the governor is set.

d. Dome pressure-relief valve.—If the pilot by mistake unfeathers the propeller until the pitch-changing mechanism reaches the positive low-pitch stops, the oil pressure will build up on the outboard side of the piston. The dome pressure-relief valve is designed to prevent damage to the dome should this occur. It is integral with the distributor-valve housing, and relieves the oil from the outboard side of the piston to the inboard side of the piston. Newer models incorporate a dome-dumping type distributor valve. During the unfeathering operation, the piston moves inboard. When the blade angle is about 15° above the minimum low-pitch setting, the outboard side of the piston is connected to the inboard side of the piston through the dump port on the distributor valve.

37. Operation and adjustment of controls.—*a. General.*—(1) An engine equipped with a hydromatic propeller is started with the propeller control in a low-pitch (high rpm) position. This position reduces the load on the propeller, and the result is easier starting and warm-up of the engine. It is normally the position of the propeller prior to stopping the engine.

(2) The means of adjusting the governor and governor controls, and cautions in regard to operation of the controls, are similar to those for the Hamilton Standard constant-speed propeller and governor (see par. 29). In the electric-head governor, the adjusting screws incorporated with the micro switches and spring-compressing gear provide for readjustment of the maximum and minimum rpm settings.

b. Preflight check-up.—After the engine warm-up during the preflight inspection, the range of operation of the Hamilton standard hydromatic propeller is checked as follows:

(1) With the propeller control in the low-pitch (high rpm) position, open the throttle to an intermediate engine speed, for example 1,800 rpm.

(2) Slowly move the propeller control toward the high-pitch (low rpm) position and note the decrease in engine rpm.

(3) Without disturbing the throttle, slowly move the propeller control toward the low-pitch (high rpm) position and note the increase in engine rpm. If both the decrease and increase in engine rpm are indicated on the tachometer, the propeller and governor are functioning properly.

(4) As an additional check, set the propeller control to obtain 1,800 rpm. Without disturbing the setting of the propeller control, slowly move the throttle back and forth. If the tachometer indicates that the engine speed remains fairly constant at 1,800 rpm, the propeller and governor are functioning properly.

38. Feathering and unfeathering.—In case of an emergency, when it is necessary to feather the propeller in the shortest possible time, the instructions given in *a* below for emergency feathering should be followed. When the propeller of one engine is being practice-feathered in flight, the remaining engines must be operating satisfactorily and the airplane must be between 5,000 and 10,000 feet above the surface over which flight is made. The period of time the propeller is left in the feathered position must not exceed 15 minutes. Otherwise, during the feathering operation, the quantity of oil forced into the engine nose may be great enough to seep down past the piston rings of the lower cylinders and into the combustion chamber of the engine. If this oil is not removed before the propeller is rotated, serious damage to the engine may result. The following instructions apply when feathering and unfeathering the propeller in flight:

a. Emergency feathering.—(1) Close the propeller feathering switch.

(2) Close the throttle.

(3) Move the mixture control to the idle cut-off position (depending on the type of engine and carburetor).

(4) Turn off the fuel supply.

(5) Leave the ignition switch on until the propeller stops windmilling and then turn it off.

b. Practice feathering.—(1) Close the throttle.

(2) Move the mixture control into the idle cut-off position.

(3) Turn off the gasoline supply to the engine.

(4) Close the propeller feathering switch or valve.

(5) Leave the ignition switch on until the propeller stops windmilling; then turn it off.

c. Unfeathering (return from feathering).—(1) Turn the ignition switch on with the throttle closed.

(2) Set the propeller cockpit control to the minimum-rpm (high pitch) position.

(3) Turn on the fuel supply.

(4) Move the mixture control to the full-rich position.

(5) Close the propeller feathering switch or valve and keep it closed until the tachometer reaches 800 rpm. Then pull out the switch.

(6) Allow the engine to operate at this rpm until the required temperature is obtained. Then open the throttle gradually, until the engine speeds up to the minimum rpm, for which the governor has been set.

(7) Adjust the mixture control.

(8) Adjust the throttle and governor setting to the desired power and engine rpm, and synchronize with the other engines.

39. Removal and installation.—The hydromatic propeller may be said to consist of three subassemblies: the hub and blade assembly (which includes the propeller retaining nut and front cone), the distributor-valve assembly, and the dome assembly. Removal or installation of the propeller involves the removal or installation of each individual subassembly.

a. Removal of propeller.—The steps in the removal of the propeller are as follows:

(1) Before attempting to remove any propeller, *see that the engine ignition switch is in the OFF position.*

(2) For engines which have crankcase ventilation through the propeller shaft, remove the breather-cup lock wire, the breather cup, and the dome breather-hole seal and washer from the front of the dome. For engines having other means of crankcase ventilation, remove the dome-seal-nut lock wire, the dome-seal nut, and the dome breather-hole seal and washer.

NOTE.—Have a pail handy to catch the oil that will flow out when the dome-seal nut or breather cup is removed.

(3) Using blade beams, put the propeller blades in the full feather position. The last tooth on one end of each blade gear segment will then rest against a stop pin in the barrel support block. The oil on the outboard side of the piston will be forced out through the breather hole into the bucket rather than being drained back to the engine sump.

(4) Install the dome lifting handle in the dome breather hole.

(5) Remove the cotter pin and lock screw that safety the dome retaining nut.

(6) Using the special composite wrench and a bar, loosen the dome retaining nut.

(7) Back off the dome retaining nut and pull the dome assembly straight out in alignment with the shaft, being careful not to let it rest on the distributor-valve assembly and the breather tube, if one is used.

(8) Remove the dome-to-barrel oil seal and gear preload shim.

(9) Using blade beams, turn the blades toward low pitch until the last tooth on the other end of each blade gear segment strikes a stop pin. Care should be taken not to turn the blade too hard and strike the stop pin, as this will chip the tooth of the blade gear segment. The blades now have been turned through zero blade angle to a reverse low-pitch position. In this position the teeth of the blade segments will not interfere with the removal of other parts of the propeller assembly.

(10) Remove the lock wire from the propeller retaining nut. It is extremely important that this wire be removed before unscrewing the distributor-valve housing assembly, in order to prevent shearing of the valve-housing lock splines. The pin of the propeller retaining-nut lock wire extends through a locking slot in the retaining nut and the aligned hole in the propeller shaft, and into a slot between two splines of the distributor-valve housing. Both the nut and the housing are thus safetied to the shaft.

(11) As a precaution to make certain that the lock wire has been removed, loosen the propeller retaining nut a few turns using the retaining-nut tubular wrench, the composite wrench, and a bar.

(12) Unscrew and remove the distributor-valve assembly, using the composite wrench, adapter, and a bar.

(13) Unscrew the propeller retaining nut from the shaft. As the retaining nut is backed off, the front cone acting against the spider snap ring pulls the propeller forward until the nut reaches the end of the propeller-shaft threads.

(14) Remove the snap ring, retaining nut, and front cone, being careful not to let the halves of the cone fall off the retaining-nut flange.

(15) Install a thread guard, and with hoist and straps remove the propeller from the shaft.

(16) To complete the removal, the rear cone is removed from the propeller shaft.

b. Installation of propeller.—After the propeller shaft has been carefully prepared for installation according to general maintenance instructions (par. 79), the installation is accomplished as follows:

(1) Coat the propeller and shaft splines, and the front cone and

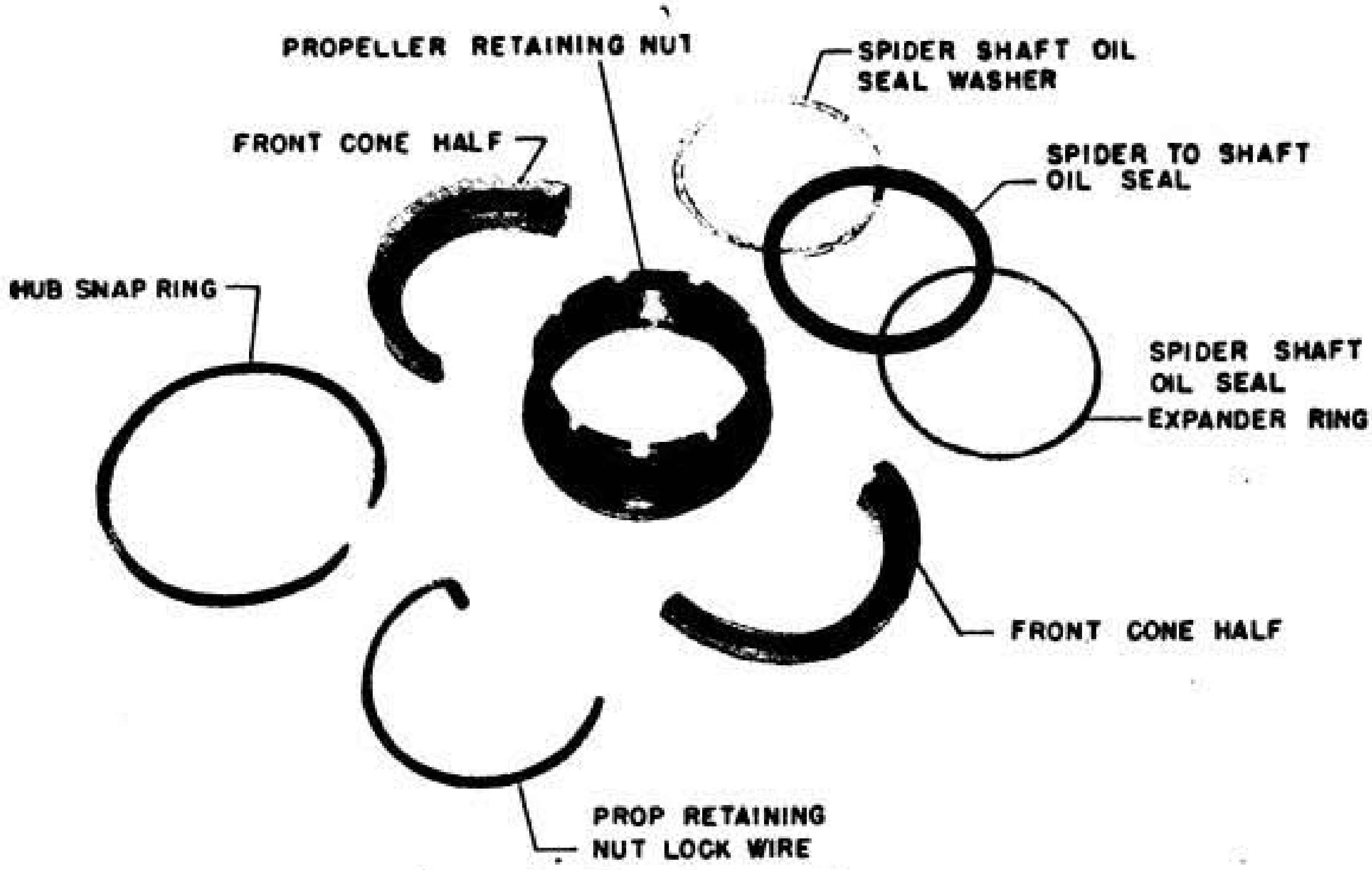


FIGURE 63.—Propeller attaching parts.

its seat with clean engine oil. The rear cone should be installed dry.

(2) Install a thread guard on the end of the shaft. Using a hoist and hoist straps, carefully install the propeller hub and blade assembly on the propeller shaft, sliding it well back against the rear cone. Put the blades in reverse low pitch so that the gear-segment teeth will not interfere with the installation of other parts. Remove the thread guard.

(3) The spider-to-shaft oil seal may now be installed. The aluminum washer, oil seal, and expander will be assembled against the spider and shaft splines in that order. This should be done by hand to avoid damaging the seal.

(4) Assemble the front-cone halves on the retaining nut (fig. 63) and screw the nut on to the shaft as far as it will go by hand.

(5) Check to be sure that the $\frac{1}{32}$-inch copper gasket is in place against the adapter flange inside the propeller shaft.

(6) Check the oil transfer plate on the base of the distributor-valve housing assembly to be sure that it is properly in place with the $\frac{1}{32}$-inch copper gasket between it and the valve housing. Be sure that the correct type of transfer plate is used—either with the hole through the center, for engines with crankcase ventilation through the propeller shaft; or without the hole through the center, for engines having other means of crankcase ventilation (see fig. 64).

(7) Oil the threads of the distributor-valve housing assembly with clean engine oil and screw it into the shaft, tightening it

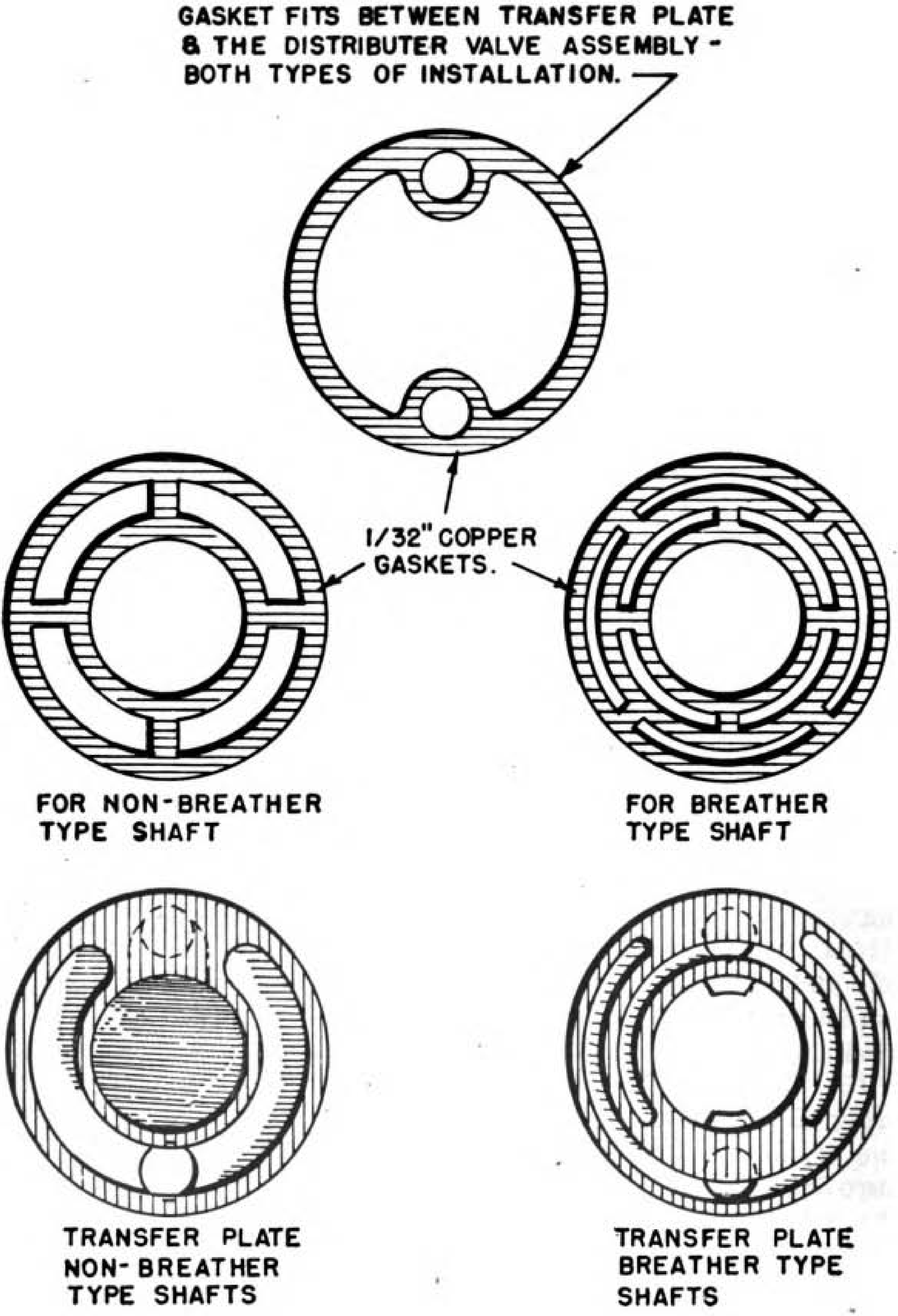


FIGURE 64.—Transfer plates and gaskets.

with a composite wrench, an adapter, and a 1-foot bar. Apply a force of approximately 100 pounds at the end of the bar and, while this force is being maintained, strike the bar near the wrench one light blow with a hammer weighing not more than 2½ pounds. If the locking slots in the valve housing are not aligned with the holes in the propeller shaft, repeat this tightening operation until the slots and holes are in alignment. ***Caution:*** Under no conditions should the valve housing be backed off even slightly in order to obtain slot-and-hole alignment. If alignment cannot be obtained, the $\frac{1}{32}$-inch copper gasket between the transfer plate and the distributor-valve housing should be lapped slightly to reduce its thickness, or a new gasket should be used.

(8) Tighten the propeller retaining nut on the shaft, using the tubular retaining-nut wrench together with a composite wrench and a 3-foot bar. Apply a force of approximately 180 pounds at the end of the bar and, while this force is being maintained, rap the bar close to the wrench with a hammer weighing about 2½ pounds. See whether one of the locking slots in the nut is in alignment with one of the holes in the propeller shaft. If not, repeat the tightening procedure until one slot and one hole are in alignment. Spacing of the slots in the nut is such that alignment of a slot and hole will occur at each 5° of rotation.

(9) Install the lock wire with the pin through the retaining-nut slot and the propeller-shaft hole and into the valve-housing slot. Snap the wire into position in the groove provided for it in the retaining nut. Install the snap ring. On propellers for engines having crankcase ventilation through the propeller shaft, check the breather tube to be sure that it is screwed tightly to the distributor-valve housing and safetied with a brass wire through a slot in the skirt of the breather tube and through the hole drilled into the dome-pressure duct in the valve housing. ***Caution:*** When installing the breather tube, extreme care should be taken to insure that the threads are started properly and that the torque for tightening does not exceed 120 pounds-feet. This precaution is necessary to avoid damage to the valve housing and gasket.

(10) Before installing the dome assembly on the propeller, check to insure that the low- and high-angle-limit adjustments are correct. If readjustments are necessary, remove the stop rings by inserting No. 10–24 screws in the tapped holes provided for this purpose. The low-angle stop ring is marked "Set to low pitch" on one lug and "Assemble this stop first" on the other lug. Reinstall the low-angle stop ring to the desired low-angle limit by inserting it so that the arrow on the stop ring coincides with the

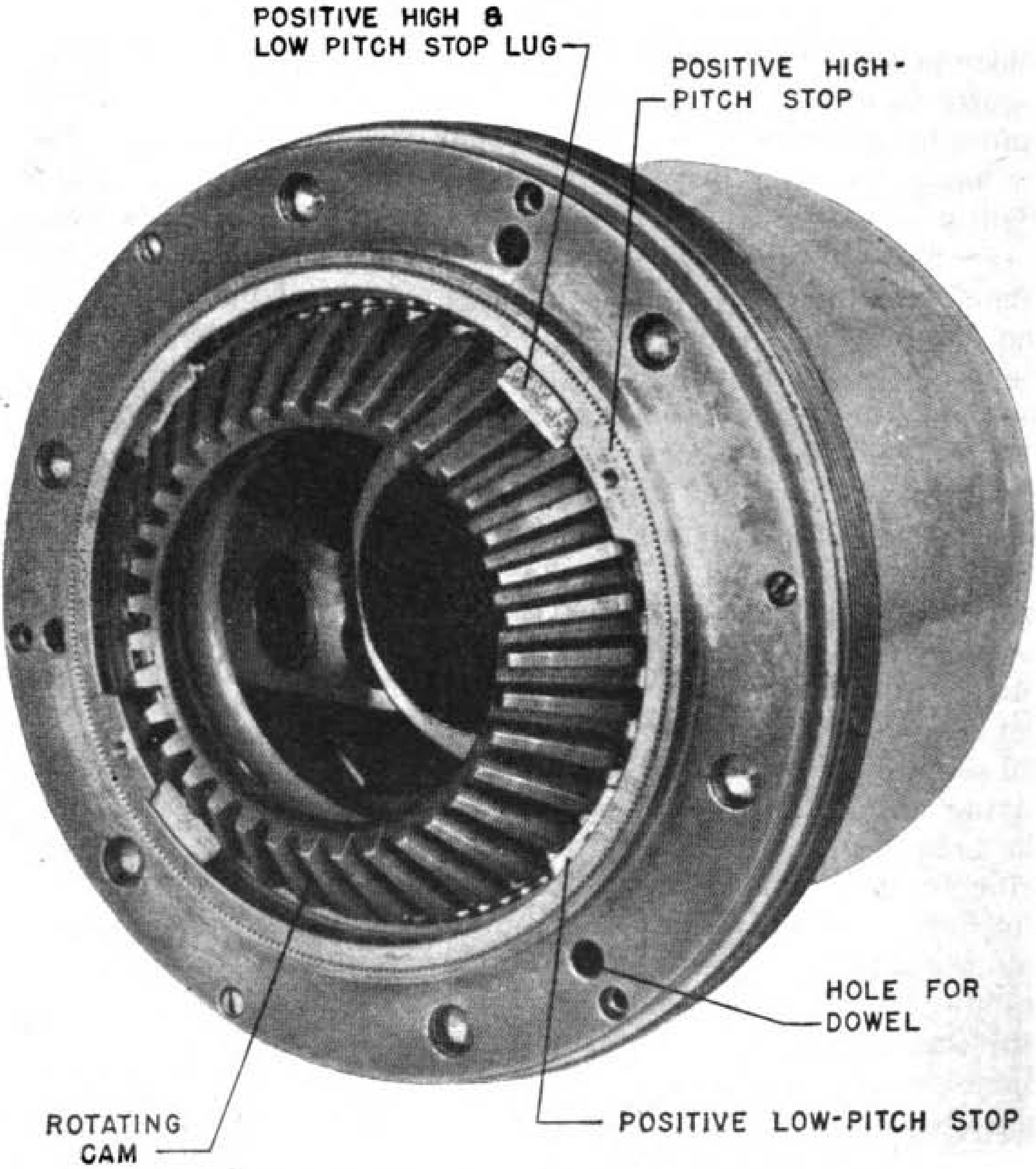


FIGURE 65.—Dome assembly, with rotating cam in full-feather position.

desired degree-mark stamped on the stop locating plate integral with the stationary cam. The high angle stop ring is marked "Set to high pitch" on one lug and "Assemble this stop last" on the other. It is reinstalled so that the arrow on it coincides with the desired degree mark on the stop-locating plate. The stop lug on the rotating cam gear marked "Set within graduations" must be within the graduated arc of the stop-locating plate after the stop rings have been installed (fig. 65). The piston of the dome assembly must be in the extreme forward position. This position will be reached when the cam-gear stop lugs are against the high-angle stops. A feathering tool, essentially a puller, is provided to move the cams and piston to this position.

NOTE.—If the dome assembly is removed with the propeller in the full-feather position or it has not been found necessary to disassemble the dome assembly in order to clean it, these adjustments will be unnecessary during installation.

(11) Check to see that the dome breather-hole seal has been removed, and install the dome handle in the breather hole. Make certain that the dome-to-barrel oil seal is properly installed around the stationary cam base against the dome, and that the necessary preload shims are installed against the dome-shelf of the barrel.

(12) Turn each blade to the full-feather position against the stop pins. Care should be taken not to turn the blade too hard against the stop pin, as this will chip the tooth of the blade gear segment.

(13) Carefully slide the dome assembly over the end of the valve assembly, making sure that the four oil-seal rings on the valve assembly enter properly into the sleeve inside the piston. An arrow is etched near one dowel pin on the barrel shelf, and another is etched near a dowel hole in the stationary cam. These must be aligned to insure proper propeller balance. Turn the dome in a *counterclockwise* direction until the dowels engage the aligning holes. (Turning the dome assembly in a clockwise direction in order to align the dowels and holes should be avoided, since this will tend to move the lugs on the rotating cam away from the high-angle position and thus allow the gears to mesh incorrectly.) The cam gear and blade gears are now in proper alignment. Slide the dome assembly, without turning it, into the barrel, until the dome retaining nut can be started. On engines which breathe through the propeller shaft, make sure that the breather tube on the front end of the valve assembly is properly started in the hole in the front of the dome.

(14) Tighten the dome retaining nut by applying a force of

approximately 180 pounds at a 4-foot radius (use a 3½-foot bar and the composite wrench). Do not use a hammer for tightening this nut. With the dome assembly properly seated in the barrel, the front face of the dome retaining nut is approximately flush with the edge of the barrel.

(15) Install the dome retaining-nut screw, and safety the screw with a cotter pin.

(16) Install the dome breather-hole oil seal, washer, and the dome seal nut or breather cup. Safety with the lock wire.

(17) With the aid of blade beams, shift the propeller into full-low pitch and check all blade angles. These angles should be equal and should agree with the low-angle stop setting. This important check indicates that the correct relationship between the blade gears and the cam gear has been obtained.

(18) Check all external screws, nuts, etc., for proper safetying.

c. Removal of governor.—The steps in the removal of the hydromatic governor are as follows:

(1) The electric head may be removed as one unit. On governors with a mechanical head, disconnect the cockpit control from the governor. If it is necessary to remove a mechanical-head governor temporarily between propeller overhaul periods, the control should be moved to the extreme rear (decrease-rpm) position, and the pulley, or lever and shaft should be marked and removed from the control shaft. This will permit reinstallation in exactly the same position and will facilitate the adjustment of the control system.

(2) On governors having external piping, disconnect the pipe connections.

(3) Remove the four mounting stud nuts.

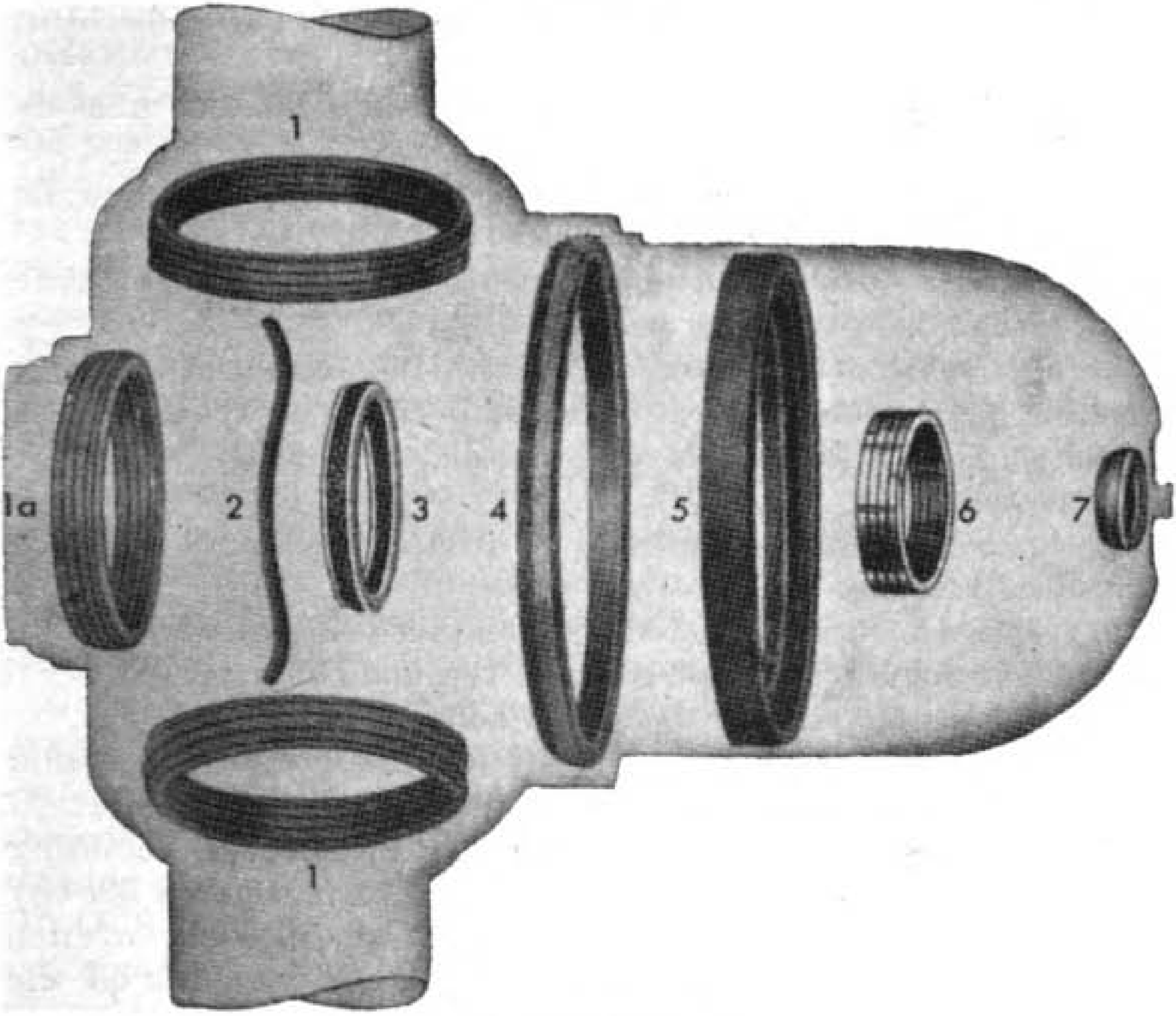
(4) Remove the governor.

d. Installation of governor.—The procedure for installing the hydromatic propeller governor is the same as that for the Hamilton standard constant-speed propeller governor (see par. 31*d*). The electric head may be installed as a single unit.

40. Inspection and maintenance.—Reference should be made to section XI. Specific inspections on the hydromatic propeller and governor follow:

a. Preflight inspection.—Before each flight, the operation of the propeller and governor is checked as described in paragraph 37*b*.

b. Oil leaks.—At the inspection periods specified in Technical Orders, the hydromatic propeller should be carefully checked for oil leaks. Sluggish operation may be the result of internal leakage,



1. Blade-to-barrel packing.
1a. Spider-to-barrel packing.
2. Barrel-half oil seal.
3. Spider-to-shaft oil seal.
4. Dome-to-barrel oil seal.
5. Piston gasket.
6. Valve-assembly oil-seal rings.
7. Dome breather-hole seal.

FIGURE 66.—Oil seals, hydromatic propeller.

caused by defective $\frac{1}{32}$-inch copper gaskets on either side of the oil transfer plate, by a defective piston gasket, or by defective oil-seal rings at the forward end of the distributor-valve assembly. Sluggish operation may also be caused by leakage at the engine collector ring or in the governor, or by loose governor control cables or push-pull rods. External oil leakage should be traced to discover in which of the following locations it occurs (fig. 66):

(1) *Front of dome.*—The dome breather-hole oil seal may be defective. If the propeller has a breather cup and tube, either the breather-hole oil seal or the breather-tube gasket may be defective.

(2) *Between dome and barrel.*—The dome-to-barrel oil seal may be defective.

(3) *On shank of blade or blades.*—Blade-to-barrel packing may be defective.

(4) *Between barrel halves.*—The barrel-half oil seal or seals may be defective.

(5) *Behind rear cone.*—The spider-to-shaft oil seal may be defective.

(6) *Between barrel and spider at rear.*—This would indicate a defective spider-to-barrel packing.

c. Importance of correcting oil leaks.—It is essential that any oil leak be corrected before flight. If a check on the tightness of bolts and nuts fails to correct the leak, the defective seal must be replaced.

d. Visible safeties.—The visible safeties should be checked periodically. These include—

(1) The dome-seal nut or dome breather-cup lock wire.

(2) The dome retaining-nut lock screw and cotter pin.

(3) The cotter pins on the barrel bolts.

(4) The anti-icing equipment safeties. The coupling hose and slinger ring screws are safetied with brass wire.

e. Propeller retaining nut.—In checking the propeller retaining nut for looseness, the procedures outlined in paragraph 39*b*(8) should be closely followed. The propeller retaining-nut wrench and a 3-foot bar should be used to make the check. Back off the retaining nut, and then tighten it. Apply a force of approximately 180 pounds at the end of the bar, and while this force is being maintained, rap the bar close to the wrench with a hammer weighing 2½ pounds. (It is not necessary to remove the valve assembly, but care should be taken to prevent damage to it by the wrench.)

f. Dome assembly.—Whenever the dome assembly is removed from the propeller, it should be visually inspected for deposits of sludge and carbon. If excessive deposits are discovered, the dome assembly must be partially disassembled and cleaned. This will be done by removing the stationary cam screws, and then removing the piston and cam assembly from the dome shell. Do not disassemble the cams and the piston. The cams, the piston, and the inside of the dome shell should be washed in gasoline to remove carbon and sludge deposits. Upon completion of cleaning, reassemble the dome assembly and reinstall it on the propeller. ***Caution:*** Great care should be exercised when handling the dome assembly, especially when it is disassembled. The cams operate with great force, and may cause severe injury to personnel carelessly fingering the cam slots.

g. If an airplane equipped with hydromatic propellers is not

to be used for several days, the propellers will be feathered and unfeathered. This is done in order to remove deposits of carbon or sludge from the propeller hydraulic system, and thereby eliminate the possibility of corrosion of the parts during the period of idleness. Each engine is operated until the required oil temperatures are reached. The engine is then stopped, and the engine sump-drain plug removed. The oil is drained in a suitable container and disposed of in accordance with existing instructions covering used oil. The propeller may then be feathered and unfeathered. This procedure is necessary to prevent the oil pumped from the propeller from collecting in the engine crankcase. Upon completion of the feathering and unfeathering cycle, the engine-sump drain plug will be reinstalled and the oil system serviced.

h. Lubrication.—The pitch-changing mechanism is fully inclosed and lubricated by oil under pressure from the governor. Consequently, special or periodic lubrication is not necessary.

i. Governor.—Inspection and maintenance of the hydromatic-propeller governor are generally the same as for the Hamilton standard constant-speed propeller governor (see par. 32). At the periods specified in Technical Orders, the following inspections should be performed on the electric head, if used:

(1) Remove the covers of the control unit and switch box, and examine for loose or dirty connections. Clean and tighten them where necessary.

(2) Replace all defective wiring.

(3) Remove the brush and spring assemblies from the control-unit motor. Brush boxes and binding brushes should be wiped clean with a cloth moistened with unleaded gasoline. Brushes worn to a length of $^{11}/_{32}$-inch or less should be replaced. Replace the covers of the control unit and switch box.

(4) At each major engine overhaul the control unit and switch box should be removed from the airplane and sent to an authorized overhaul depot for complete disassembly and inspection.

SECTION VII

AEROPRODUCTS PROPELLER

41. General.—*a.* The Aeroproducts propeller is a hydraulically operated, constant-speed propeller. A separate pitch-changing mechanism is contained in each blade socket. This type of construction leaves an unrestricted opening through the center of the propeller hub, permitting the installation of an aircraft cannon. For this reason, current models of the Aeroproducts propeller are being used on fighter airplanes carrying cannon that fire through the propeller shaft.

b. The oil pressure required to operate the pitch-changing mechanism in each hub socket is supplied by a regulator assembly mounted on the rear of the hub. This unit contains its own oil supply and is entirely independent of the engine lubricating system. It also contains a pump and a governor. The governor meters the oil under pressure from the pump to the blade sockets to operate the pitch-changing mechanism. A large blade-angle range and a rapid rate of pitch change make it possible for this governor to maintain a constant engine speed throughout all normal pursuit maneuvers.

42. Description.—*a. Hub.*—The hub assembly of the Aeroproducts propeller consists of the hub and the pitch-changing mechanism. The hub supports the other main units of the propeller. It is made from a solid steel forging that is drilled through the center and splined to fit the propeller shaft. The blade sockets are then drilled out, and surfaces are properly machined to receive the other units of the propeller assembly, that is, the regulator assembly, the pitch-changing mechanism, and the blades. Oil passages for carrying oil under pressure to and from the blade sockets are drilled in the rear of the hub (fig. 67).

b. Blade assembly.—The blades are of hollow steel construction, and have a longitudinal rib running throughout the length of the blade, from the blade tip to the shank. This rib strengthens the blade, cnabling it to resist the stresses on it, and also eliminates much of the propeller vibration normally encountered.

(1) The blade is constructed of two members which are copper-brazed together. The main member is the thrust member. It is a machined forging forming the blade shank, the thrust face, the longitudinal rib, and the leading- and trailing-edge reinforcements. The camber member is a formed sheet which is attached to the forging by copper brazing.

(2) Over the straight shank of the blade thus formed are fitted a blade retaining nut, a stack of angular contact bearings, and a bearing-stack retaining nut. The blade nut is threaded to the blade shank and holds the bearing stack in place. When the blade is

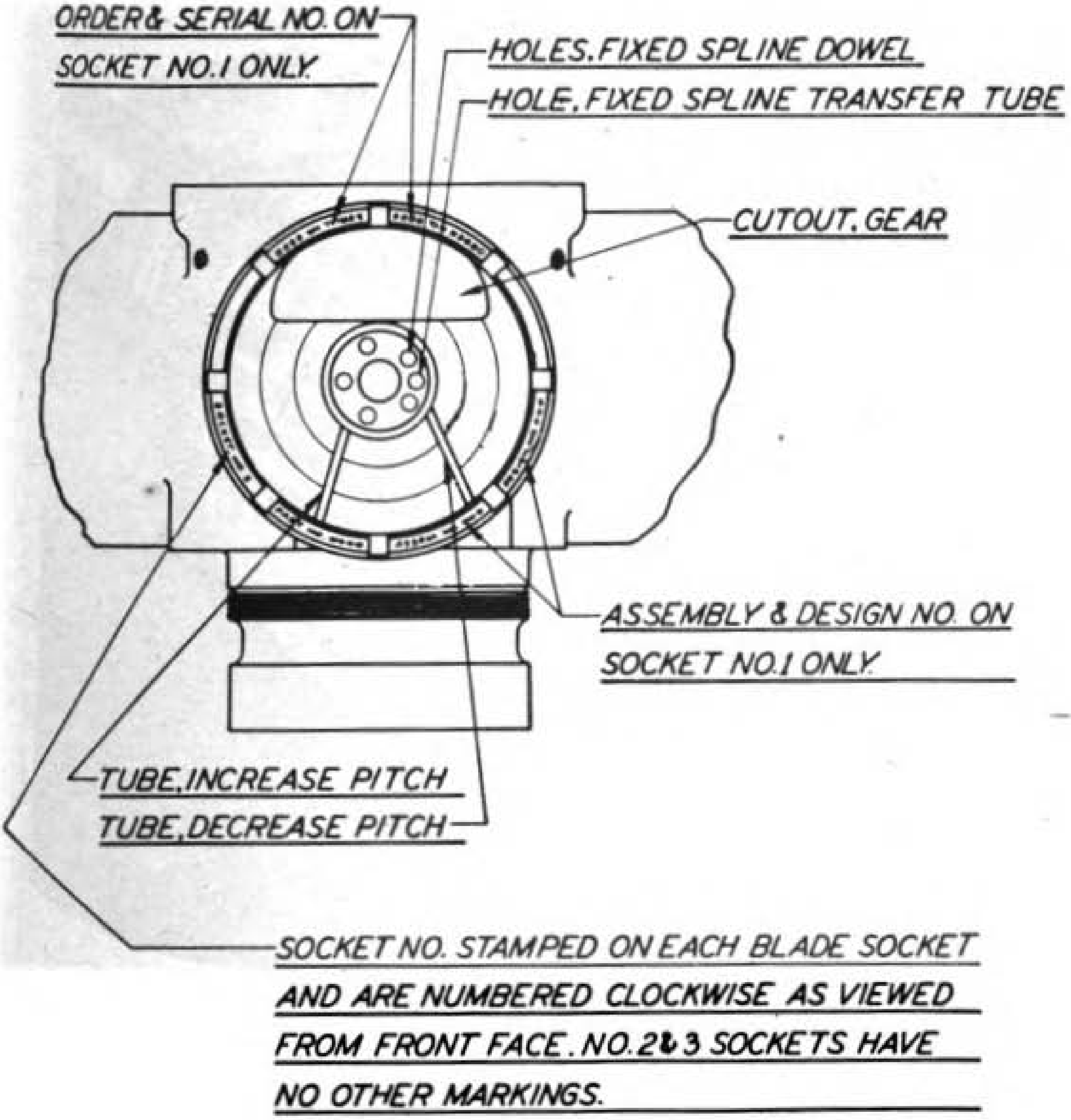


FIGURE 67.—Hub of the Aeroproducts propeller.

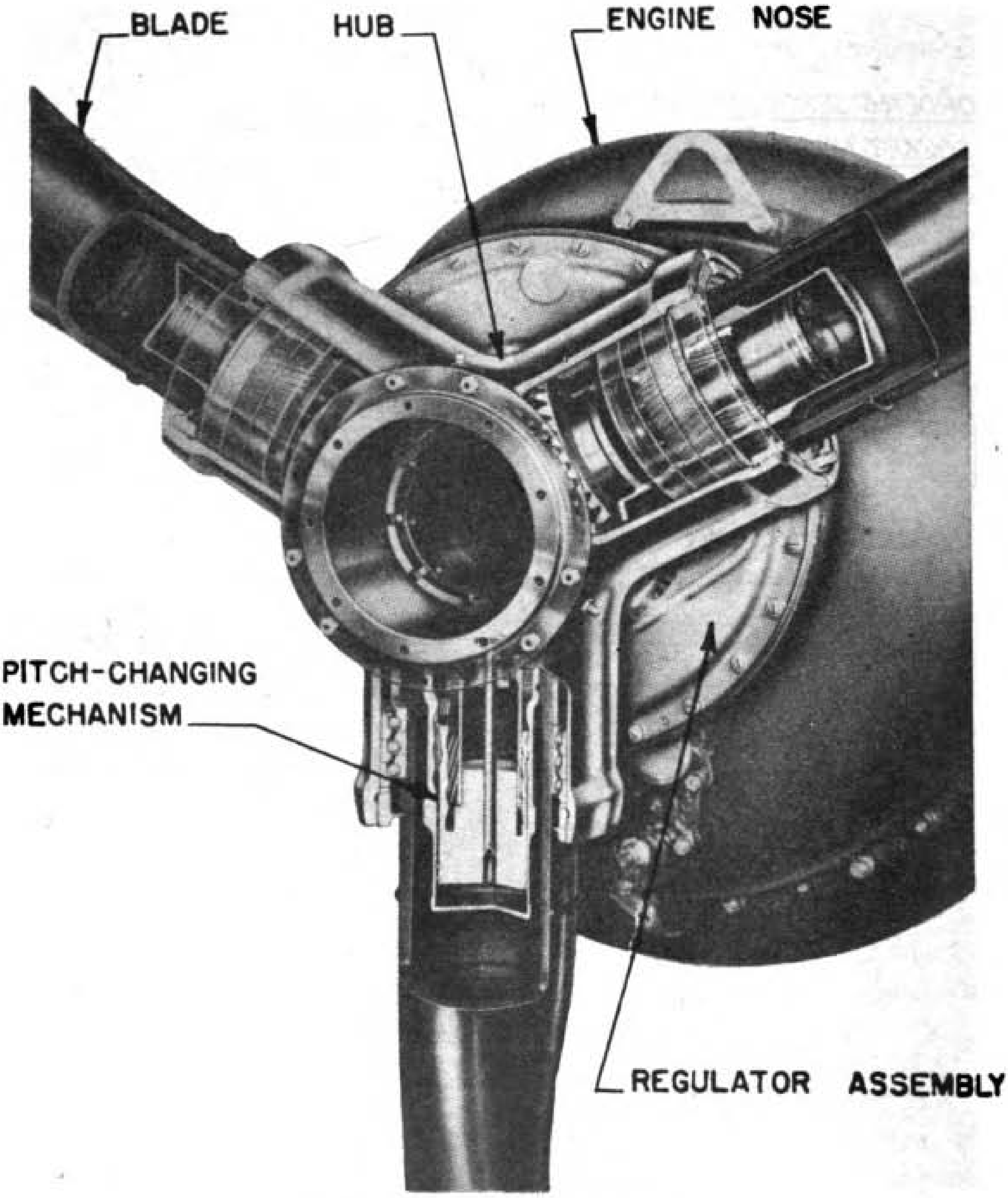
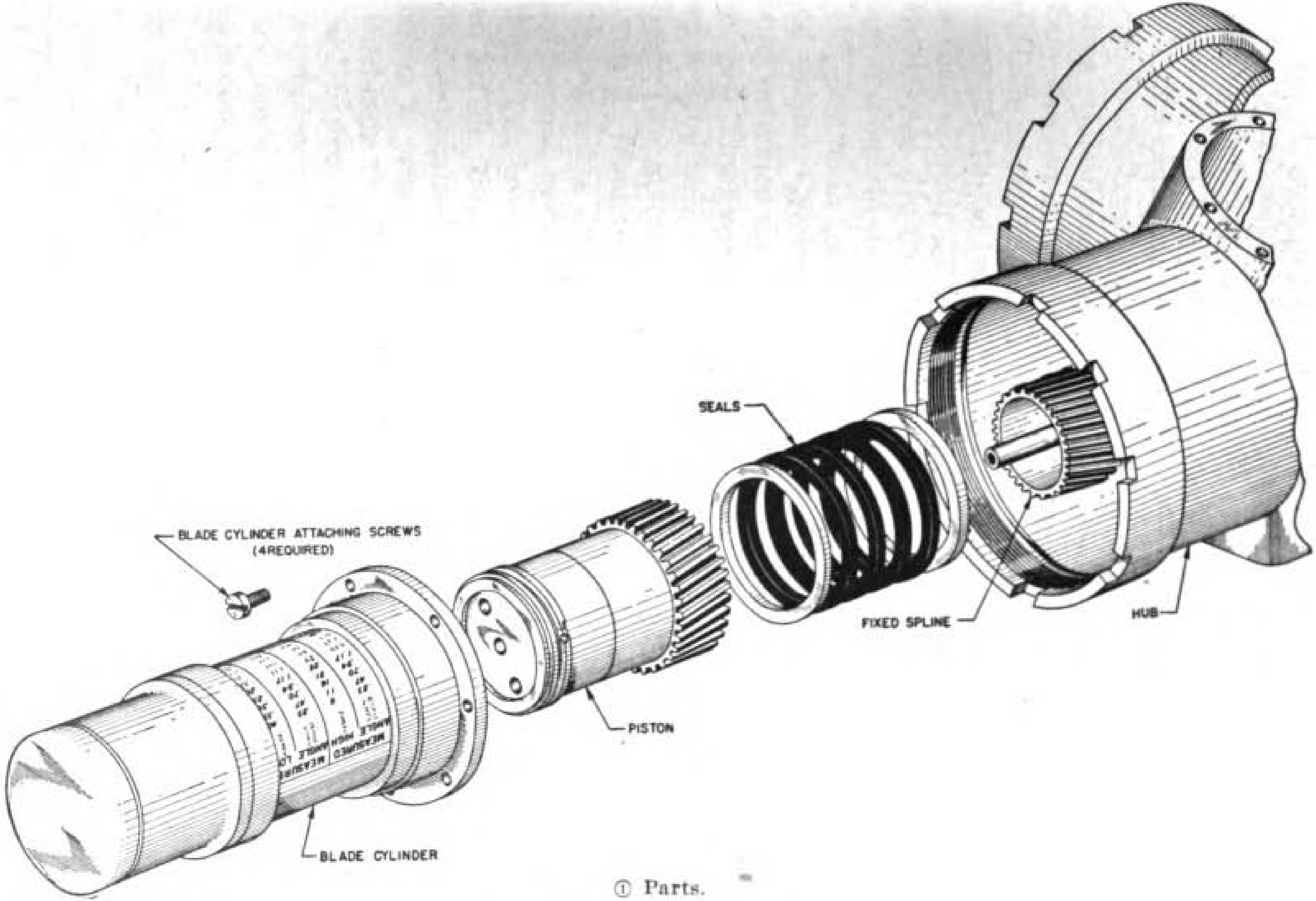
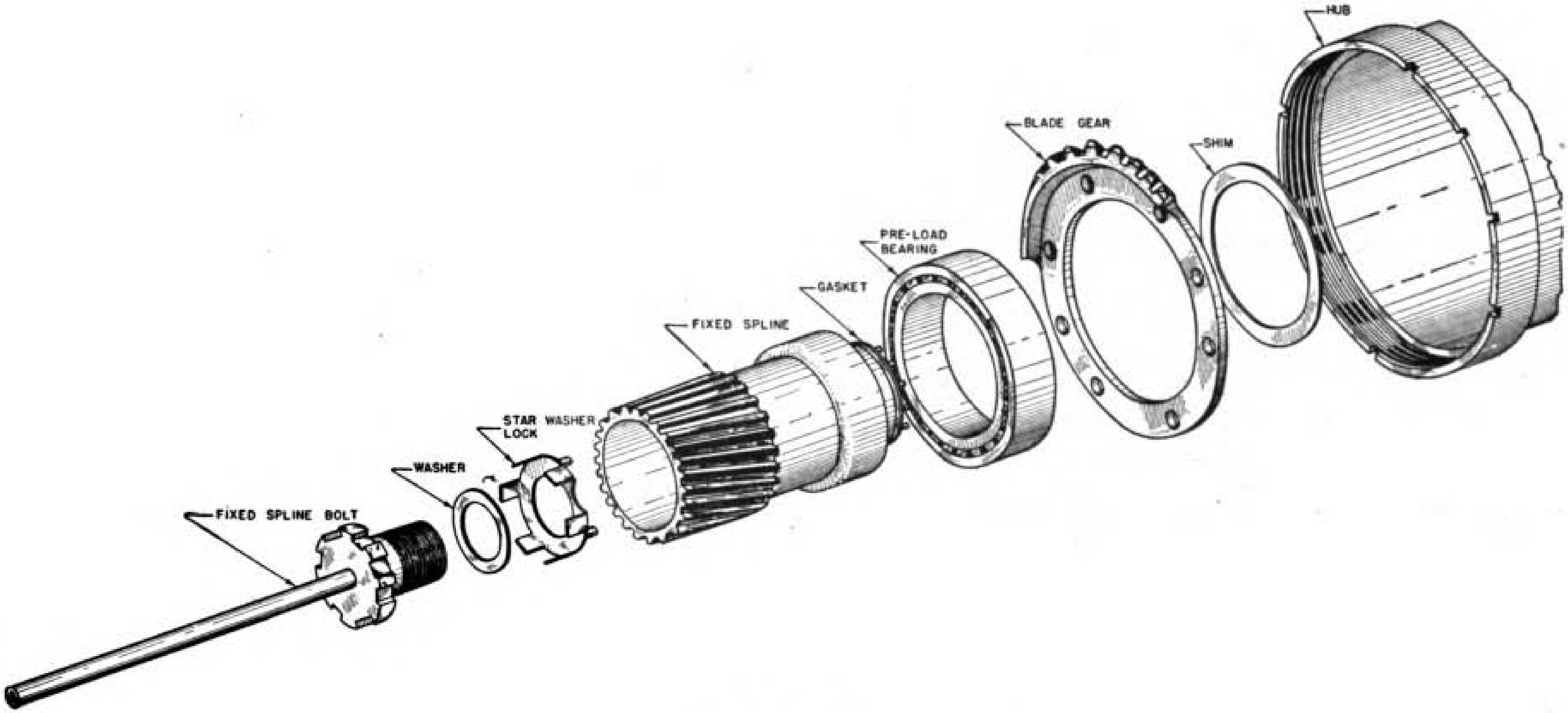


FIGURE 68.—Aeroproducts propeller.



① Parts.

Figure 69.—Torque unit.



② Exploded view.

FIGURE 69.—Torque unit—Continued.

placed in its socket and the blade retaining nut is threaded into place, the bearing-stack retaining nut acts as a shoulder to retain the blade in the hub. The blade root has four dowels that engage four dowel holes in the cylinder skirt when the blade is installed in the blade socket. The blade retaining nut is provided with a spring-loaded neoprene seal for retaining lubricant in the bearing stack.

c. Pitch-changing mechanism.—The pitch-changing mechanism consists of a torque unit in each blade socket (fig. 68). The torque unit is so designed that the axial motion of a piston will result in rotary motion of a cylinder attached to the blade, and thus change the blade angle. This is accomplished by having helical (sometimes incorrectly called "spiral") splines on the three main members of the torque unit, namely, the cylinder, the piston, and the fixed spline. (See fig. 69; frequent reference to this figure should be made during the following discussion.)

(1) The main part of the torque unit in each blade socket is the fixed spline. Cylindrical in shape, it is doweled and bolted to a mount provided for it in the center of the base of the blade socket (fig. 69). The fixed spline has external helical splines that engage the internal helical splines of the piston, which fits over the fixed spline. The piston also has external helical splines of opposite curvature from its internal helical splines, that is, they "spiral" in the opposite direction. The cylinder fits over the piston, and it has internal helical splines that engage with the external piston splines. The inward and outward movement of the piston on the fixed spline, due to oil pressure, results in rotary motion of the cylinder because of this spline arrangement. The torque of the cylinder is transmitted to the blade by means of the four dowels on the blade that fit into holes in the skirt of the cylinder (fig. 69).

(2) To provide an oil passage to the outer side of the piston, a long tube extends outward from the fixed-spline bolt through the piston head. This fixed-spline bolt screws into the center of the fixed spline base, which is connected by a tube to a hole in the rear face of the hub. Thus oil under pressure metered by the governor from the regulator passes through the tube from the rear of the hub to the center of the fixed-spline base, and hence through the tube from the fixed-spline bolt to the outer side of the piston (oil passage No. 1). (See fig. 69.) Oil pressure on the outer side of the piston forces it to move inward and causes the blade to rotate to a lower pitch.

(3) An oil passage to the inner side of the piston is provided by a hole at the side of the fixed spline which matches with another

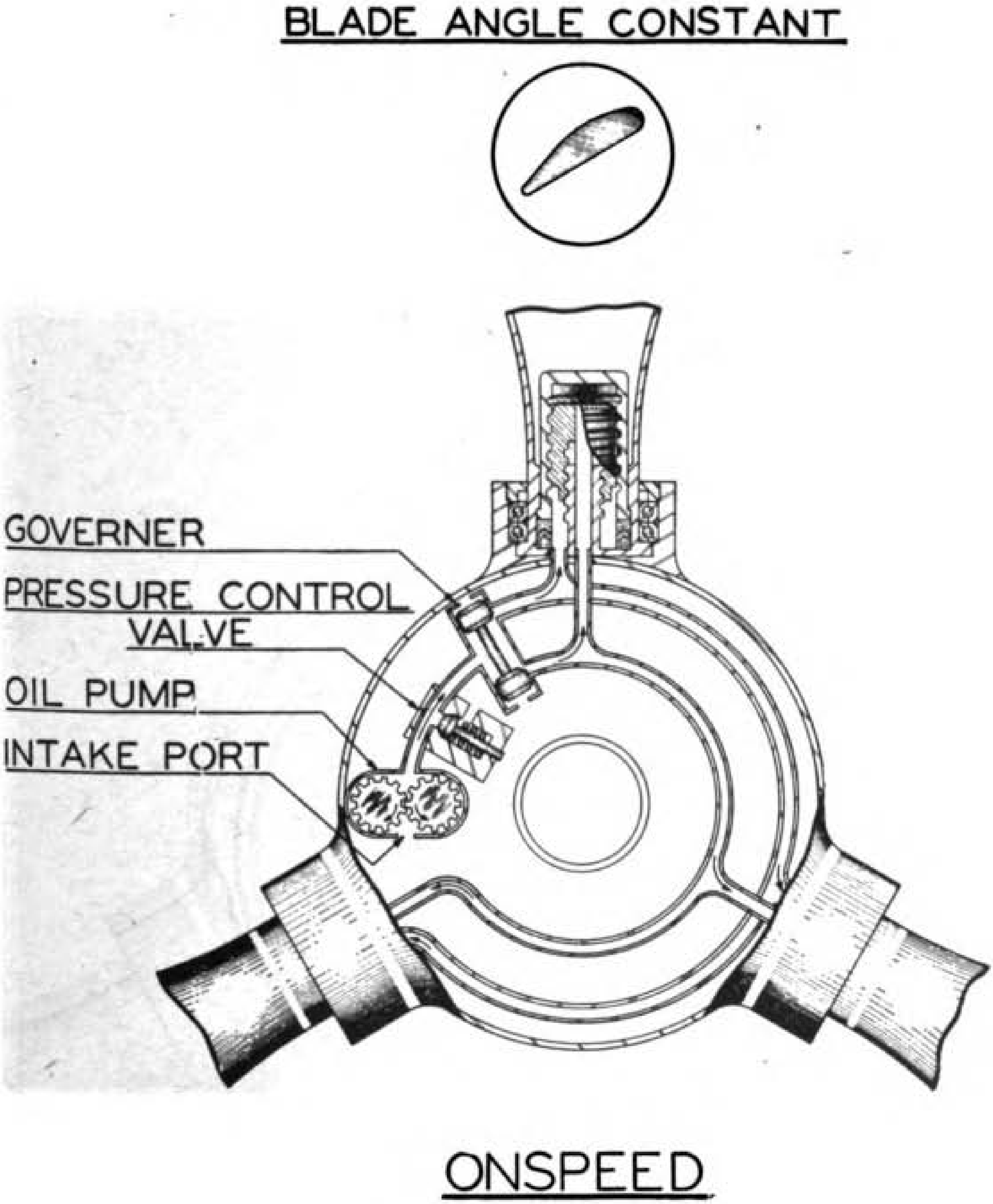
hole at the side of the fixed-spline base (oil passage No. 2). (See fig. 69.) Oil under pressure metered by the governor from the regulator passes through a tube from the rear of the hub to the hole at the side of the fixed-spline base, and thence to the inner side of the piston. Oil pressure on the inside of the piston forces the piston outward and causes the blade to rotate to a higher pitch.

(4) To coordinate the blade angles of the several blades, a blade gear sector is doweled to each blade root, and is also held by screws to the cylinder skirt. A master or coordinating gear is mounted in the front of the hub and is retained in place by a master-gear retaining plate that is bolted to the front face of the hub. The master gear engages the gear sectors on the several blades. Frictional differences between the torque units in the several blade sockets are thus overcome, and all the blades are kept at the same angle.

d. Regulator assembly.—A two-way hydraulic pressure system for operating the pitch-changing mechanism is provided by a regulator assembly. This unit is mounted on the rear of the hub, between the blade sockets and the nose of the engine. The housing, cover, and fixed part of the regulator assembly form an oil reservoir; thus the oil supply for operating this propeller is entirely independent of the engine lubricating system. Within the regulator assembly and mounted on the housing are three basic hydraulic units: a pump, a pressure-control valve, and a propeller governor (fig. 70).

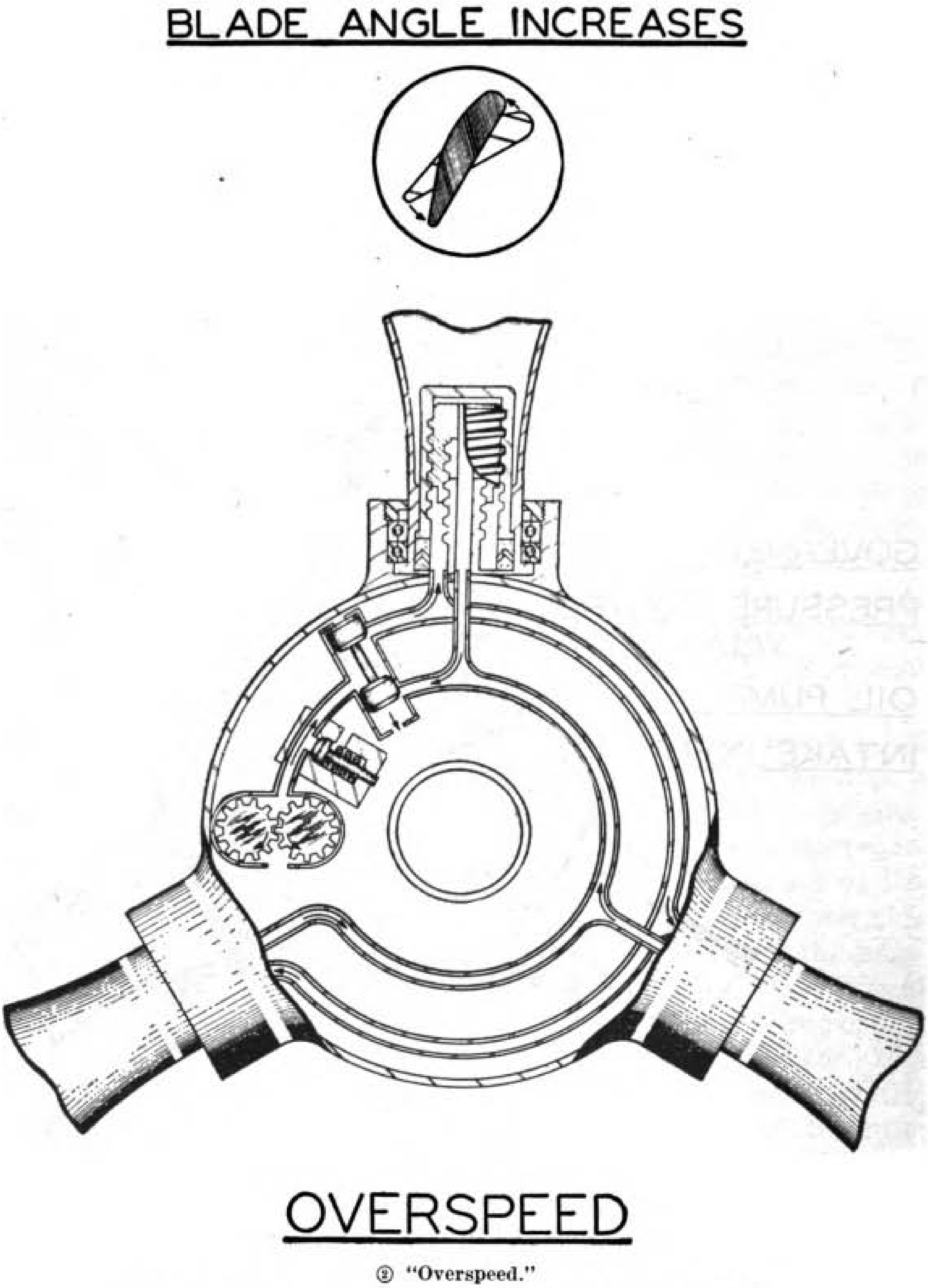
(1) To provide for the passage of oil between the several hydraulic units and to and from the holes in the rear of the hub, a tube assembly is cast in the aluminum-alloy regulator housing. This tube assembly consists of a high-pressure tube, a decrease-rpm tube, and an increase-rpm tube. The oil is pumped out of the reservoir by means of the gear-type pump (mounted on one side of the housing) and through the high-pressure tube and the pressure-control valve to the governor (mounted on the other side of the housing). The high-pressure tube goes to the center port of the three located at the distributor valve of the governor. The decrease-rpm tube carries the oil under pressure metered by the governor from the outside port to holes in the rear of the hub. These holes connect with the inside of the blade pistons. The increase-rpm tube carries the metered oil under pressure from the inside port to holes connecting with the outside of the blade pistons (fig. 70).

(2) The pressure control-valve setting varies for different models. It should be set to open at the pressure specified (in Tech-



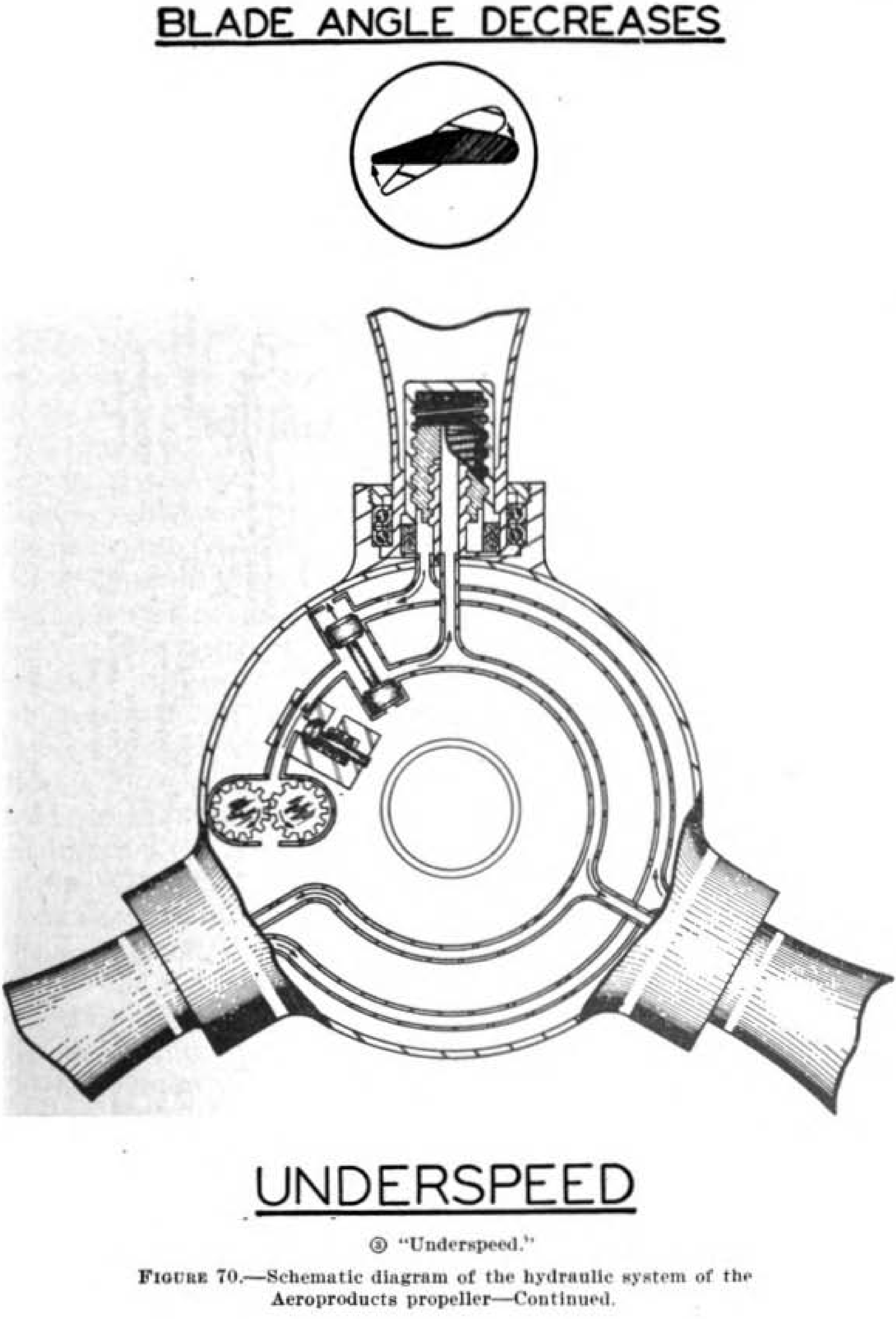
① "On speed."

FIGURE 70.—Schematic diagram of the hydraulic system of the Aeroproducts propeller.



② "Overspeed."

FIGURE 70.—Schematic diagram of the hydraulic system of the Aeroproducts propeller—Continued.



③ "Underspeed."

FIGURE 70.—Schematic diagram of the hydraulic system of the Aeroproducts propeller—Continued.

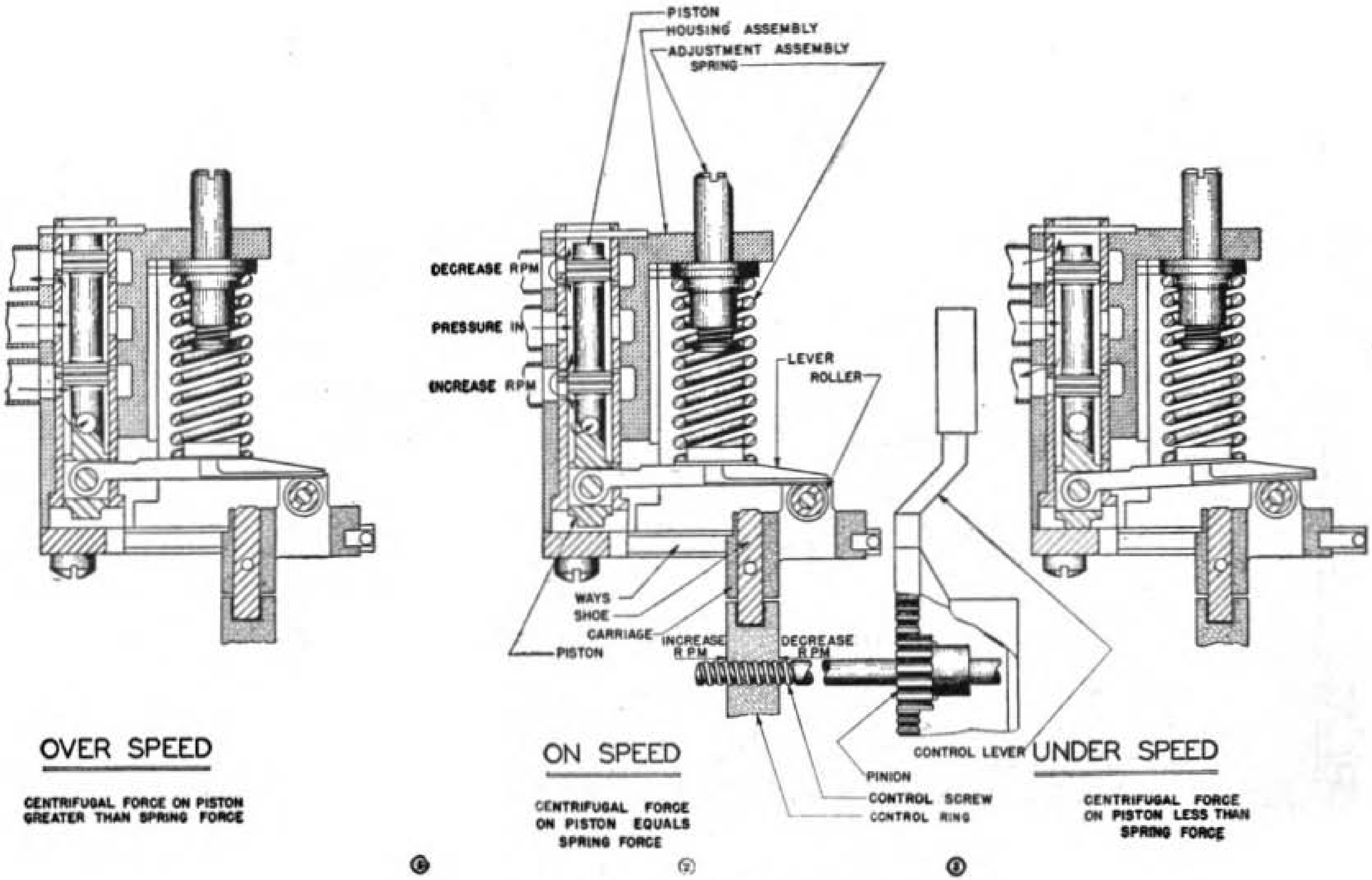


FIGURE 71.—Operation of the governor.

nical Orders) for the particular model. Because of centrifugal force, this pressure increases as the propeller speed increases.

(3) The governor assembly is mounted on the regulator housing. It is placed in such a manner that, when the propeller, and therefore the housing and governor, are rotating, centrifugal force tends to cause the governor piston (which acts as a flyweight) to move away from the propeller shaft. Opposing the centrifugal force on the piston in the governor is the action of a compression spring. The operation of the governor depends upon the state of balance or unbalance existing between these two forces. This is explained in the following paragraphs.

(4) The governor piston is part of the governor distributor-valve assembly. The cylinder of this assembly is pressed into the governor housing. Passages in the housing admit oil to three holes in the steel cylinder. The center hole is connected to the high-pressure line from the pump. The piston regulates the flow of oil into or out of the other two holes. The size of these openings has a definite relation to the amount of "off speed." Fluid may return to the reservoir from either end of the piston (fig. 71).

(5) Opposition between centrifugal force on the piston and the spring action of the compression spring is obtained by attaching a lever to the piston. This lever extends into the reservoir and has attached to it one end of the compression spring, the other end of which is attached to the aluminum body of the governor. The lever is supported by a roller, which runs on steel ways. This roller provides a movable pivot, or fulcrum, by means of which the relation between the two opposing forces may be varied to obtain different engine rpm (fig. 71).

(6) With the fulcrum set in any normal position, centrifugal force tends to throw the piston outward. This motion is resisted by the spring acting through the lever system. In an "on speed" condition, the force of the spring acting on the lever is exactly balanced by the centrifugal force of the piston (fig 71②). In this case, the piston covers both the increase-rpm and decrease-rpm holes in the distributor valve equally. Under these conditions the oil pressure on both sides of the blade pistons is equal, and the pitch of the blades remains constant. An increase of engine speed will increase the centrifugal force on the governor piston, so that its effect on the lever will be greater than that of the spring. This is an "over speed" condition. The governor piston will move outward, opening the decreas-rpm tube to the high-pressure oil, and the increase-rpm tube to the reservoir (fig. 71①). Oil will flow from the pump to the inner side of the blade pistons, forcing them out and thereby

increasing the pitch of the propeller. The increased pitch will cause the engine to slow down, and the slowing dow of the engine will in turn bring the governor piston back to its "on speed" position. On the other hand, a decrease in engine speed from the "on speed" rpm will result in an "underspeed" condition. In this case the spring force will govern. The governor piston will be moved inward, opening the increase-rpm to the reservoir (fig. 71⑥). Oil will flow from the pump to the outer side of the blade pistons, forcing them in and thereby decreasing the pitch of the propeller blades. The decreased pitch will cause the engine to speed up, and the speeding up of the engine will in turn bring the governor piston back to its "on speed" position. The governor in this manner keeps the engine operating at a constant speed.

(7) The main body of the regulator assembly is attached to the hub by means of a ring nut. Over this ring nut fits the fixed part of the propeller, which completes the regulator assembly. On some models, the fixed part of the propeller is keyed to the engine reduction-gear case in the following manner: a key of one or two pieces is fixed to the gear-case studs, and a keyway in the adapter plate of the fixed part of the propeller matches this key. On other models the fixed part of the propeller is held by nuts to the engine reduction-gear-case studs. Either of these methods will prevent the rotating propeller from turning the fixed part of the propeller.

(8) Two high-speed oil seals are installed between the rotating and fixed parts of the regulator assembly. This makes the regulator assembly oiltight and thus provides an oil reservoir which contains the fluid to operate the pitch-changing mechanism. These high-speed oil seals are of neoprene and are spring-loaded.

(9) An aluminum-bronze gear that drives the pump engages with a gear on the fixed part of the propeller. Also mounted on the fixed part of the propeller are a bronze control ring, three control screws and pinion gears, a gear-supporting ring, and a contol lever, all of which are part of the governor control. A description of these parts and their locations follows.

(10) In order that the pilot may choose the engine rpm he desires, a governor control consisting of a mechanical linkage from the cockpit propeller control to the roller fulcrum of the governor is required. By means of this linkage, the engine rpm can be controlled by changing the position of the roller fulcrum on the lever (fig. 71). The roller fulcrum is mounted on a carriage so that it may slide back and forth on steel ways. Attached to this carriage is a governor shoe or ring sector which rides in the groove of the control ring mounted on the fixed part of the propeller. Three con-

trol screws are threaded into this ring and extend rearward through the fixed part of the propeller. At the rear end of these control screws and integral with them are pinion gears. The control lever is part of a large ring gear that engages the pinion gears, and both the lever and the gears are mounted on a gear-supporting ring. A flexible linkage from the cockpit propeller control to the control lever completes the governor control.

(11) The engine rpm can be controlled by the operation of this governor control. Forward movement of the cockpit control will move the control lever and ring gear in a clockwise direction (viewed from the cockpit). This movement of the ring gear will rotate the pinion gears and control screws in a clockwise direction. The control ring will travel rearward on the control screws and carry the fulcrum assembly with it toward the end of the lever. With the fulcrum in this position the spring force becomes more effective, and the governor piston moves inward. Oil under pressure is directed to the pitch-changing mechanism, decreasing the pitch and increasing the engine rpm until the increased centrifugal force on the governor piston moves it into an "on speed" position. Rearward movement of the cockpit propeller control will have a result opposite to that outlined above.

(12) From this description it can be seen that the compression spring and the lever arm are accurately constructed so that each position of the fulcrum corresponds to a definite "on speed" engine rpm. The mechanical linkage of the governor control makes it possible for the pilot to change the position of the fulcrum by means of the cockpit propeller control, and thereby select the engine rpm that he desires.

43. Principle of operation.—*a*. The regulator assembly contains in itself a two-way hydraulic pressure system for operating the pitch-changing mechanism. The housing, cover, and fixed part of this assembly together form an oil reservoir. Cast in the housing is a tube assembly which forms the "plumbing" system of the propeller. The pump is driven by a gear which engages a stationary gear on the fixed part of the propeller. It supplies oil under pressure to the governor through the pressure tube of the tube assembly. (Frequent reference should be made to fig. 72 while reading this discussion.)

b. The governor determines to which side and in what quantity the oil under pressure is metered to the blade pistons in order to maintain the engine at a constant speed.

(1) In an "on speed" condition, the two forces in the governor are in balance. The governor piston is in such a position that oil

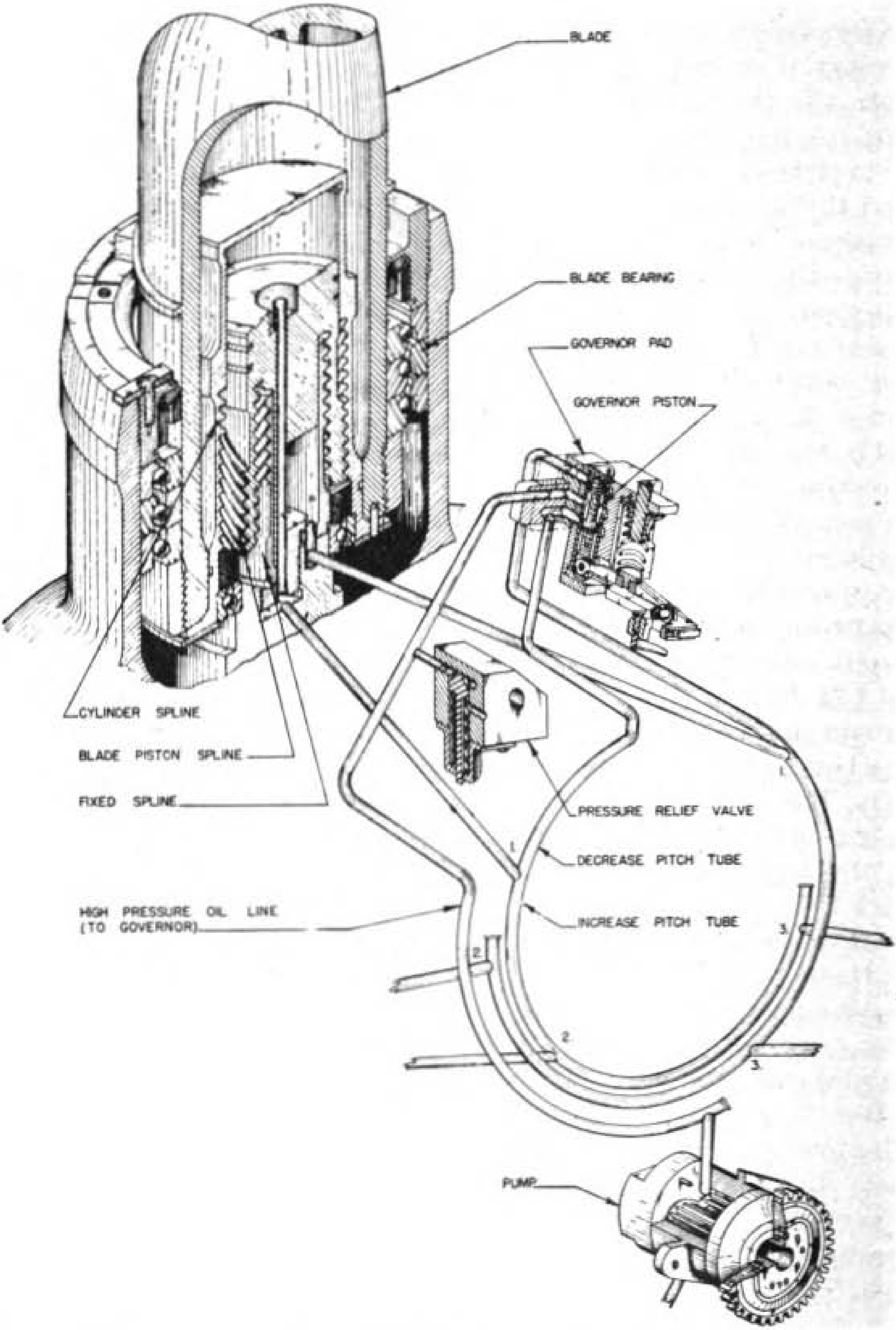


FIGURE 72.—Pitch-changing mechanism and hydraulic system of the Aeroproducts propeller.

flows equally to both sides of the blade pistons. The blade angles remain constant, and the engine continues to rotate at the rpm for which the governor cockpit control is set.

(2) If a change in airplane attitude causes the engine to "overspeed" momentarily, the increased centrifugal force on the governor piston forces it to move outward. In this case the decrease-rpm tube leading to the inner side of the blade pistons is opened to the high-pressure tube, and the increase-rpm tube is opened to the reservoir. Oil pressure on its inner side forces the blade pistons to move outward, and the action of the helical splines on the three main parts of the torque unit causes the blades to rotate to a higher angle. The blades take a larger "bite," the engine speed decreases to an "on speed" condition, and the governor piston assumes an "on speed" position.

(3) A momentary decrease in engine speed will cause the governor piston to move inward because of a decrease in centrifugal force. This movement realigns the distributor-valve ports in such a manner that oil pressure is directed to the outer side of the blade pistons. As the blade pistons move inward and the blades rotate to a lower angle, the decreased load on the blades causes the engine rpm to increase until the engine is again "on speed." The governor piston returns to its "on speed" position, stops the flow of oil to the torque units, and holds the blade angle constant.

44. Preflight operation.—*a*. A preflight operation check is made to determine whether the governor control linkage is operating properly, and also whether the proper range of operation may be obtained. The procedure follows.

(1) Check the oil level in the regulator (see par. 46*h*).

(2) Start and warm up the engine.

(3) Place the cockpit propeller control forward in the take-off rpm position and advance the throttle enough to get an engine speed of approximately 2,300 rpm. *"Run up" of the engine on the ground using full military power should be avoided.*

(4) While adjusting the throttle to maintain a constant manifold pressure, move the propeller control to the decrease-rpm position.

(5) Replace the propeller control in the take-off rpm position, holding the manifold pressure constant. Note a gradual rise in engine rpm to approximately 2,300 rpm and note that the throttle is in its original position. This indicates that the propeller is operating properly.

(6) After installation of a new or overhauled propeller, repeat this procedure three times to purge the propeller hydraulic system of air; the propeller should then operate properly.

(7) After stopping the engine, recheck the oil level in the regulator.

b. With a new or overhauled propeller, it is necessary to make a ground test and test flight after the preflight operation to determine whether the propeller control will give the proper engine rpm for take-off and full military power. If the desired maximum rpm is not obtained, the governor may be adjusted to give a higher or lower maximum-rpm setting. The procedure for adjustment follows.

(1) The maximum-governed rpm of the engine may be changed by adjusting the governor-spring adjusting screw (located just inside the filler hole). This screw has a bearing face in contact with the governor spring. Two methods are used to insure positive locking of the screw. In the old type, the bearing surface has slots which engage fixed pins (fig. 73). To adjust this type, remove the filler plug, insert a screw driver in the slot of the screw, *push the screw in approximately 1/16 inch,* and turn the screw. One-sixth turn (or 1 notch) clockwise gives a decrease of approximately 10 propeller rpm. The decrease in engine rpm depends on the ratio of the engine-to-propeller reduction gearing. Counterclockwise turning of the screw increases the rpm. The screws and slots must be aligned to insure proper locking. Instead of locking pins, the new-type governor has a fixed plate. The bottom of this plate has rounded projections. The top of the plate which bears on the spring also has rounded projections. This insures positive locking of the screw and eliminates the possibility of broken locking pins. *The mechanic should be sure which type governor he is adjusting.* After any governor adjustment, the filler plug will be installed and safetied.

(2) Before beginning the preflight and test flight of a new or overhauled propeller, a special adjustment of the governor is necessary. Turn the governor adjusting screw clockwise to the limit of its travel. Then turn the adjusting screw counterclockwise one complete turn, or six notches. After the final governor adjustment is made on a new or overhauled propeller, no further adjustment should be necessary. If, however, at any time during regular operation the engine should gain or lose in rpm at the take-off position of the propeller control, various checks and necessary corrections should be made before the governor is readjusted. The oil level in the regulator should be checked to see that it is even with the filler hole when that hole is horizontal. The rigging of the control system should be inspected, and the propeller control should be checked for full travel. The tachometer should be checked for

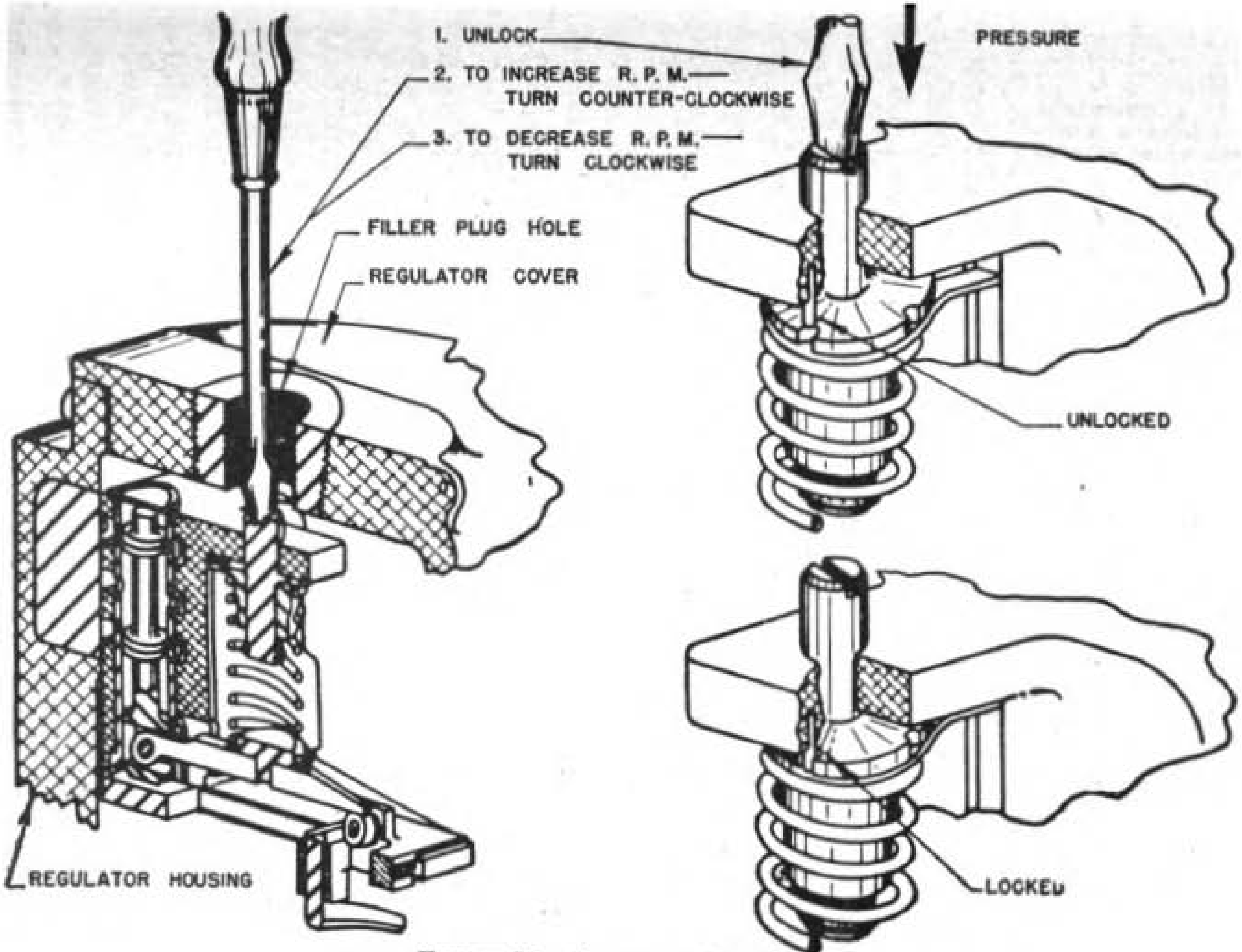


FIGURE 73.—Governor adjustment.
FIGURE 69.—Torque unit—Continued.

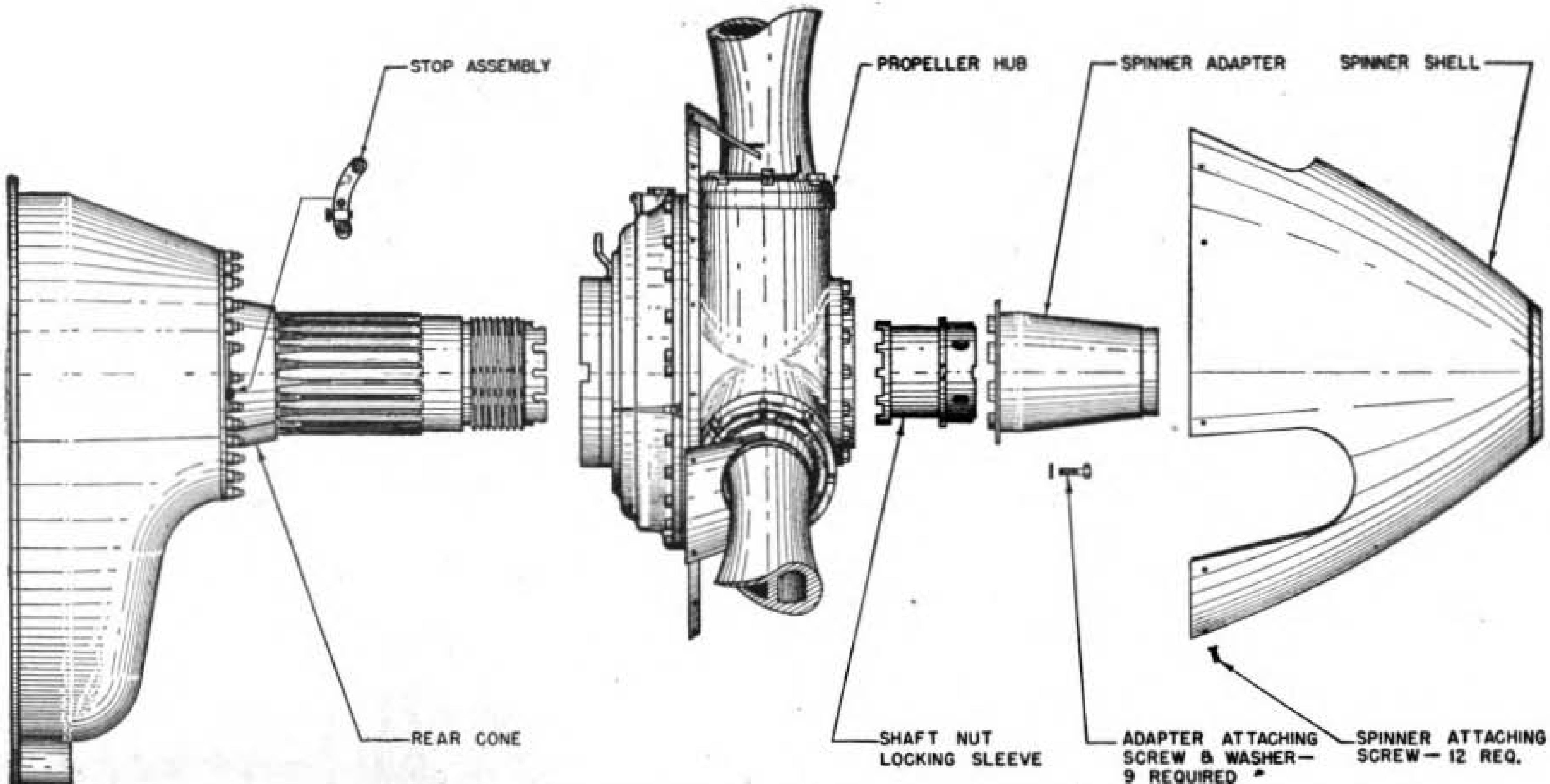


FIGURE 74.—Removal and installation diagram.

accuracy, the engine for loss of power, and the manifold pressure gauge for accuracy.

45. Removal and installation.—Because the Aeroproducts propeller is completely contained in a single unit, removal and installation are fairly simple procedures. Little disassembly and assembly are required to remove and install it (fig 74).

a. Removal.—(1) Before removing any propeller, be sure that the ignition switch is in the OFF position.

(2) For planes having tricycle landing gear, load the nose-wheel strut fork with approximately 300 pounds in order to compensate for removal of the weight of the propeller.

(3) Remove the countersunk attaching screws that hold the spinner shell to the bulkhead, and remove the spinner shell by rapping with the palm of hands only.

(4) Turn the propeller until the oil filler plug in the regulator points downward. This should bring the wide spline of the propeller shaft to the bottom.

(5) Remove the inspection doors from the cowling around the nose of the plane directly behind the spinner.

(6) Detach the governor control linkage from the control lever by removing the cotter pin and clevis pin. ***Caution:*** At this point check the fixed part of the propeller to see if it is of the bolted-on type. If it is, loosen the holding nuts as far as possible.

(7) Remove the spinner adapter by removing the safety wire and the cap screws that hold it to the face of the hub.

(8) Loosen the propeller retaining nut two turns. To do this with a cannon installed, a special wrench that will fit the locking sleeve is required. For installation without cannon, a bar may be placed through holes in the sleeve.

(9) Attach slings to the two upper propeller blades, as close to the hub as is practicable. Take a light strain on the hoist to relieve the propeller shaft of the weight of the propeller. ***Caution:*** If the fixed part of the propeller is bolted to the engine reduction-gear case, the nuts must be removed as the propeller shaft nut is backed off. Check the adapter plate of the fixed part of the propeller after each turn of the propeller retaining nut until the adapter plate is clear of the engine reduction-gear-case studs. Then loosen the retaining nut until it is clear of the threads.

(10) Exercising extreme care to prevent damaging the bore, splines, shaft, or cannon, slide the propeller forward until clear of the propeller shaft and cannon, operating the hoist as required to maintain clearance.

(11) Remove the regulator plug and drain the oil out of the regulator. Replace the plug and washer.

(12) Supporting the free blade, place the propeller carefully on a bench or other support with the regulator up.

(13) Remove the rear cone and felt insert (fig 74).

b. Installation.—(1) Examine the shaft and the rear-cone seat for nicks, burrs, or scratches, and remove any that are found. Clean the shaft and rear-cone seat with an approved cleaner. Rotate the shaft to bring the wide spline to the bottom.

(2) Install the rear cone against the thrust nut, leaving the rear cone and its seat dry.

(3) Coat the propeller shaft with clean engine oil.

(4) Apply a thin coat of approved antiseize compound to the propeller-shaft threads.

(5) Clean the inner bore of the propeller thoroughly, making sure that the front- and rear-cone seats are free of grease and dirt, and wiped thoroughly dry.

(6) Attach slings to the two blades opposite the wide spline of the propeller hub. Keep the slings as close to the hub as is practicable. ***Caution:*** Provide clearance between the sling and the spinner bulkhead plates to avoid damage when the propeller is raised.

(7) Raise the propeller, manually supporting the free blade, and align the wide spline of the hub with the wide spline of the propeller shaft. Cautiously slide the propeller on the shaft until the propeller shaft-nut engages the threads. Take care not to damage either the threads, splines, cones, or cannon.

(8) Insert the propeller retaining-nut locking sleeve into the hub, engage the nut, and screw it three turns on to the shaft, using the special wrench and/or bar.

(9) Align the adapter plate keyway with the key on the engine reduction-gear cases; or (on some models) align the adapter-plate lobes with the engine reduction-gear studs, and place the lever stop plate on the proper adapter lobe.

(10) Turn the propeller-shaft nut two turns while checking the alignment of the adapter plate with the adapter stop, or the lobes with the studs. With the latter type, place the special spacers on the studs and start the attaching nuts, but do not tighten.

(11) Continue tightening the retaining nut, observing the adapter-mounting line-up until the propeller is mounted solidly against the rear cone. Tighten all adapter-plate attaching nuts (when used) except the one at the lever stop-plate lobe.

(12) Remove the hoist slings from the propeller.

(13) While blocking one blade, tighten the propeller retaining nut, applying a force of 175 to 200 pounds at the end of a 30-inch bar.

(14) Install the spinner adapter. If attaching screw holes in the spinner adapter do not line up with screw holes in the face of the hub, remove the adapter and rotate it one notch at a time until proper alignment is made. If alignment still is not attained, it will be necessary to tighten the propeller retaining nut more. To do this, tap on the bar not over 12 inches from the center of the shaft with a rawhide hammer until the adapter can be installed.

(15) On models using a two-piece key, install and safety the block in the stop bracket.

NOTE.—If the fixed part of the propeller is of the bolted-on type, an adjustment of the control-lever stop plate is necessary at this point. Refer to Technical Orders for correct procedure.

(16) Move the control lever to one end of its travel, then move the quadrant control to see if the end of the flexible cable linkage will follow the same amount. Repeat this procedure at the other end of the range. This check will make sure that the regulator control lever is free to move throughout its full range. Be sure that there is sufficient control travel on the high-rpm side.

(17) Attach the flexible cable to the control lever by installing the clevis pin through the cable clevis and the control lever. Safety with a cotter pin.

(18) Fill the regulator with oil. (For details, see par. 46*h*.)

(19) Lubricate the propeller hub. (For details, see par. 46*g*.) In the initial lubrication a bleeder tool is used instead of removing the grease fittings. (This tool is inserted between the blade retaining nut and the blade shank, care being taken not to damage the retaining-nut seals.)

(20) Check the propeller installation to see that all screws, nuts, etc., are locked properly.

(21) Replace the spinner shell. The dowels can be aligned quickly by matching the numbers stamped on the exterior of the shell and on the face of the bulkhead. Tap the shell into place using hands only, and replace attaching screws.

c. Emergency installation.—Fully assembled propellers require shipping space, and are difficult to pack and handle. Factories and depots are therefore shipping many propellers partially disassembled. After the propeller has been carefully assembled and balanced, and the blade angles set at the factory or depot, two of the blades are removed, the third blade remaining in the hub together with the attached regulator assembly. The removed blades are

then packed with the hub, installed blade, and regulator assembly and with other propeller subassemblies and attaching parts. Shipping space is thereby conserved, and packing and handling of the propeller are more easily accomplished. Because propellers are being shipped in this manner, the mechanic must know the procedure for reassembling a partially disassembled Aeroproducts propeller. The steps in this procedure are as follows:

(1) Remove the hub with its one blade and the regulator assembly from the packing case, and place the unit on any clean surface with the regular assembly up. ***Caution:*** When handling the propeller, do not lift by the spinner bulkhead.

(2) Using clean rags, wipe the anticorrosion compound from the hub bore and the exterior of the hub and regulator. *Do not* remove the film of grease from the blade sockets of the hub.

(3) Remove the nut lock from the blade retaining nut and remove the blade end-protecting cap from one of the removed blades. Clean the anticorrosion grease from the blade exterior but *do not* remove the grease from the bearings at the shank end. Apply antiseize compound to the threads of the blade retaining nut and the hub threads.

(4) Install the blade in the hub so that the number on the blade shank corresponds with the number on the hub socket. Turn the blade in the socket until the dowels align with the dowel holes in the cylinder skirt and blade gear; then push the blade in until the dowels are engaged in the holes. Because of offset dowels and dowel holes, the blades will fit into the hub in only one way.

(5) Tighten the blade retaining nut snugly using the blade retaining-nut wrench and a 30-inch bar. Tighten the nut until the purple-painted lock slot in the blade retaining nut matches the purple-painted lock slot in the hub.

(6) Install the nut lock in the purple-painted slot of the blade retaining nut and safety.

(7) Install the anti-icer tube and clamp on the hub. Attach the flare nut at the end of the tube to the fitting on the regulator. Provide sufficient clearance between the blade shank and the end of the tube.

(8) Install the balance weights in the red-painted slots of the blade retaining nut. Provide at least 0.003-inch clearance between the end of the weight and the blade shank.

(9) Repeat the foregoing procedure with the remaining blade.

(10) Attach the spinner-bulkhead plates to the spinner bulkhead so that the cut-outs in the plates surround the blade shanks.

(11) The propeller is now ready for installation on the airplane

(see par. 46*b*). ***Caution:*** When propellers are shipped disassembled in this manner, the regulator is completely filled with the proper hydraulic fluid to prevent corrosion of regulator parts during long periods of storage. Therefore, half of this oil must be drained from the regulator after the propeller is installed. To do this, rotate the propeller until the filler plug is in a horizontal position. Remove the filler plug and drain the oil from the regulator until the oil is level with the filler-plug hole. The regulator is then half full of oil. Replace the filler plug and washer, and safety. Make absolutely certain that any spilled oil is cleaned from the regulator, spinner bulkhead, and the cowling of the airplane.

46. **Inspection and maintenance.**—Besides the general inspection and maintenance performed on all propellers (sec. XI), certain special inspections must be performed on the Aeroproducts propeller. Most important is the check for oil leaks. Immediately following is a list of the oil and grease seals used, and where, if defective, they will allow leakage.

a. Oil-seal leaks.—(1) A string type neoprene seal fits in a groove in the regulator housing. This groove is just inside the screw holes that receive the screws for holding the cover to the housing. If this seal is defective, oil will leak between the cover and housing. Loose cover-to-housing screws also would cause leakage at this point.

(2) Short transfer tubes fit in the decrease- and increase-rpm oil passages, between the regulator housing and the hub. Neoprene packings are installed around these transfer tubes, and in countersunk portions of both the hub and the housing. If the packings are defective, oil leakage between the hub and the housing will occur.

(3) Composition packings are fitted around the three control screws in the fixed part of the propeller. If one or more of these packings become defective, they will allow oil to leak around the rear of the regulator cover, between the cover and the gear-supporting ring.

(4) The housing and cover seals are the two high-speed seals installed between the housing and cover and the fixed part of the regulator assembly. Should these seals be defective, oil may leak between the hub and the housing or at the rear of the cover. If there is leakage when the propeller is stationary, but not in flight, these seals are probably "holding off" the seats.

(5) The cylinder seal is between the cylinder and the fixed spline, inward of the piston. If this seal is defective, oil will most likely appear inside of the sleeve assembly and propeller shaft. The oil will also displace the grease in the blade socket, causing one blade

to be light. If the propeller "whips" when rotating, this may be the cause.

(6) A copper washer fits under the filler plug. If it is defective, oil leakage will occur around the filler plug.

b. Locating oil leaks.—It is often difficult to determine exactly where oil leakage is occurring. A mixture of commercial whiting and alcohol is sometimes used to aid in determining the exact location of an oil leak. This mixture is placed on the parts of the propeller where oil leakage may occur, and also on the engine gear-reduction case, for this may be leaking oil. The alcohol evaporates, leaving a white deposit. The engine is run for a short period, and the oil leakage readily shows up at its exact location.

c. Internal oil leaks.—Any of the oil leaks thus far mentioned (except oil leakage from the gear box), if sufficiently great, may cause sluggish pitch-change operation. However, if no external oil leaks are apparent and sluggish operation is experienced, the cause may be one of the following internal oil leaks:

(1) Between the fixed spline and its mounting base in the hub socket is a vellumoid gasket. If the gasket is defective, there will be leakage between the decrease-rpm and increase-rpm side of the oil-pressure system.

(2) A vellumoid gasket is installed between the pressure-control valve and its mount in the regulator housing. If this gasket is defective, a low oil pressure for operating the pitch-changing mechanism will result.

(3) Between the governor and its mount in the regulator housing is a vellumoid gasket. If it is defective, oil may leak between the decrease-rpm and increase-rpm sides of the oil pressure system.

(4) Two piston-type oil rings fit in grooves in the piston head and slide on the cylinder wall. Should they become defective oil leakage will occur between the decrease-rpm and increase-rpm sides of the oil pressure system.

(5) A washer fits under the fixed spline bolt. The purpose of this washer is to prevent leakage between the increase-rpm and decrease-rpm sides of the oil pressure system.

(6) If the internal pump gaskets are defective, a low oil pressure for operating the pitch-changing mechanism will result. The source of oil leaks must be determined and the leaks corrected, before flight. If necessary, the propeller will be removed from the airplane.

d. Grease leaks.—Grease seals are required in order to retain in the blade sockets the grease that lubricates the blade bearings and

gears. There are two of these seals for each blade socket, as follows:

(1) A spring-loaded neoprene seal in a groove in the blade retaining nut and around the shank of the blade. If this seal is defective, grease will appear on the shank of the blade.

(2) A neoprene ring seal between the cylinder and the blade. If defective, it will allow grease to leak into the shank of the blade. As a result, this blade will become heavier than the other blades, causing propeller unbalance. Vibration and "whip" will be noted in the operation of the propeller.

e. In connection with the oil and grease seals and possible leaks, the instructions under *h* below should be noted. If the propeller is to operate properly, the oil level in the regulator must be kept even with the filler hole when the hole is horizontal.

f. Checking retaining nut for looseness.—To check the propeller retaining nut for looseness, the spinner shell and spinner adapter must be removed. Using the special wrench, loosen the retaining nut and tighten it again, using a force of 175 to 250 pounds at the end of a 4-foot bar. Replace the spinner adapter (which safeties the retaining nut) and the spinner shell.

g. Lubrication of hub assembly.—At the periodic inspections specified in Technical Orders, the hub assembly will be lubricated as follows:

(1) Remove two of the three grease fittings in the hub.

(2) Procure a power or a hand grease gun containing the proper grease as specified in Technical Orders. Apply the grease gun to the remaining fitting until grease appears at one of the fitting holes.

(3) Reinstall the grease fitting in the hole where grease appeared.

(4) Apply the grease gun to the replaced fitting until grease shows at the remaining hole.

(5) Reinstall the third grease fitting. (The purpose of this lubrication is to lubricate the blade bearings and the blade gears.)

h. Checking oil level in the regulator assembly.—At the periodic inspections specified in Technical Orders, the oil level in the regualtor assembly will be checked as follows:

(1) Rotate the propeller until the filler plug on the regulator housing is in a horizontal position.

(2) Remove the filler plug.

(3) If the oil is below the level of the filler hole, fill with the oil specified in Technical Orders.

(4) Replace and safety the filler plug. Whenever the governed

rpm of the engine has decreased, check the oil level of the regulator. The level of the oil in the regulator slightly affects the maximum governed speed, therefore, the proper level must be maintained.

i. Control arm and linkage.—The control arm and linkage leading to the cockpit should also be cleaned and inspected, and should be lubricated with clean engine oil as required.

j. Blades.—Besides the general maintenance performed on all steel blades, the brazed joints between the camber sheet and the thrust member should be examined for voids (spaces not filled with brazing metal). Excessive voids are cause for rejection of a blade.

k. Spinner assembly.—The spinner shell should be inspected for dents, nicks, or other damage. All dents should be removed. The attaching screws should be checked for looseness and the attaching screw holes for elongation. A check should also be made for loose rivets and loose dowels.

l. Safeties.—The safeties of this propeller should be checked, and are as follows:

(1) The control-arm clevis pin is safetied with a cotter pin.

(2) On some models, the safety on the key attached to the engine reduction-gear case should be checked. On other models the stud-nut safeties should be checked.

(3) The blade retaining nut lock, and the screw and safety wire of each blade retaining nut should be checked.

SECTION VIII

CURTISS ELECTRIC PROPELLER (THREE-BLADE MODEL)

47. Models and model designation.—*a. Designation by code.*—Several models of the Curtiss electric propeller (fig. 75) have been designed and manufactured. A code has been devised to iden-

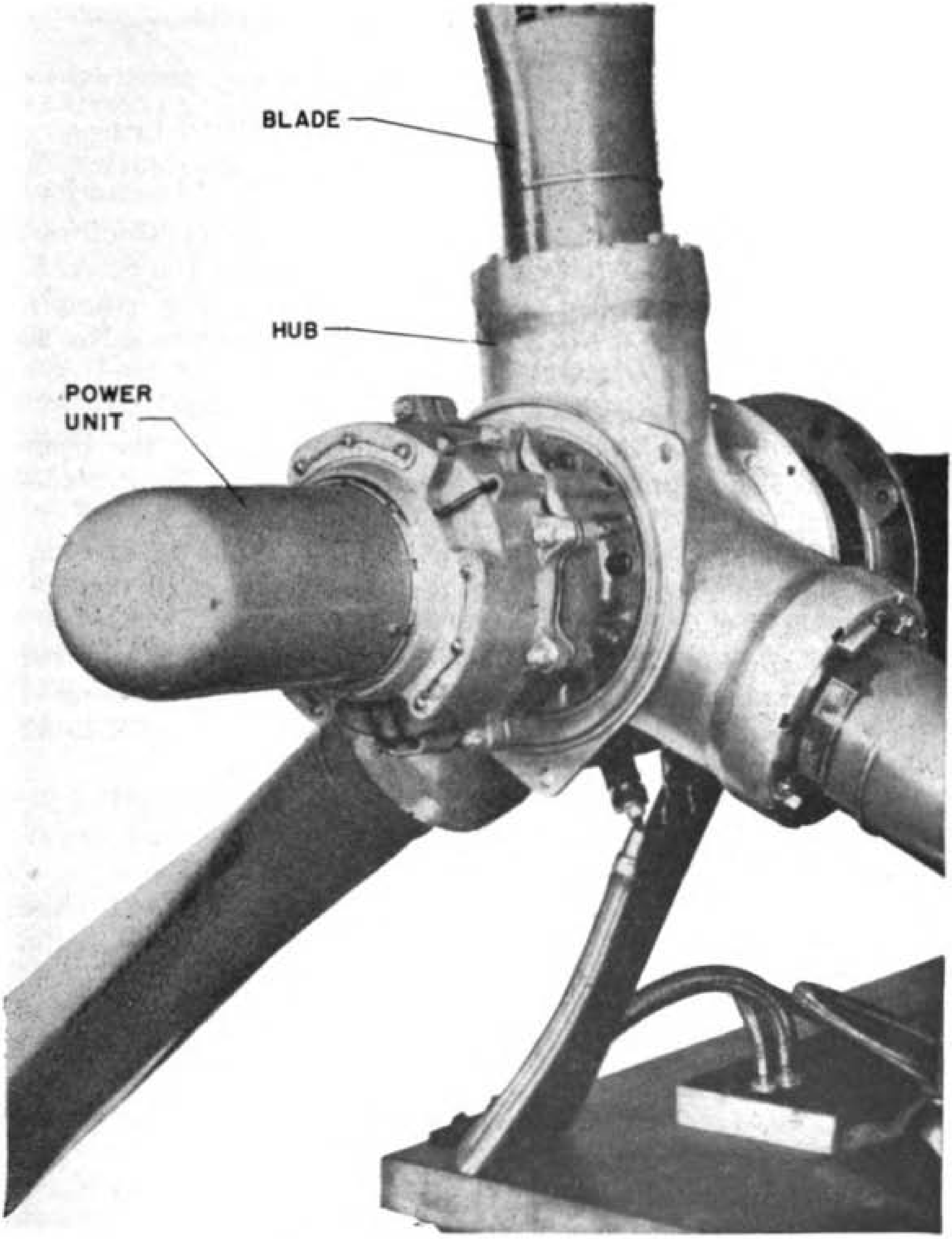


FIGURE 75.—Curtiss electric propeller.

tify these various models. Combinations of numbers and letters of the code are stamped on the hub at the end of the No. 1 blade socket. These code numbers and letters give important information about the particular model. The following is a table of various models and their code designations:

Model	*Model number*
Three-blade model	C532D–F8 C532S–C6
Hollow-shaft three-blade model	C6315SH–C4
Four-blade model	C543S–C4

(1) The first letter "C" signifies Curtiss as the manufacturer.

(2) The first digit of the model number indicates the S. A. E. standard splined shaft upon which the hub will fit. For example, the digit "5" indicates a No. 50 shaft, and "6" indicates a No. 60 shaft size.

(3) The second digit indicates the number of blades.

(4) The third (or third and fourth digit indicates the blade shank size. For example, the digit "2" indicates a No. 2 blade-shank size; "15" indicates a No. 1.5 blade-shank size.

(5) The letter immediately following digits indicates the material from which the blade is made; thus "D" is used for aluminum alloy, "S" for steel, and "W" for wood.

(6) Any additional letter included with, but after, the material designation indicates a special feature of the propeller. (Example: C6315SH–C4 indicates a hollow-shaft propeller; C5315SP–A2 indicates a pusher type propeller.)

(7) A suffix combination of a letter and one or two digits indicates the general series to which the propeller belongs and identifies the complete propeller assembly.

b. Example.—Figure 76 illustrates the markings on a Curtiss controllable propeller designated as "Model C6315SH–C4, Mfg. No. 3000." The code letters and numbers indicate the following:

C—Curtiss propeller.
6—No. 60 standard splined shaft.
3—Three blades.
15—No. 1.5 blade shank.
S—Blades of steel.
H—A hollow shaft.
C—General design series "C."
4—Specific assembly No. 4 of the preceding designations.

48. Method of pitch control.—*a. Electrical system.*—The blade-angle change of the Curtiss electric propeller is regulated by a small reversible electric motor. The electric current for operating this motor is obtained from the airplane's power supply—the bat-

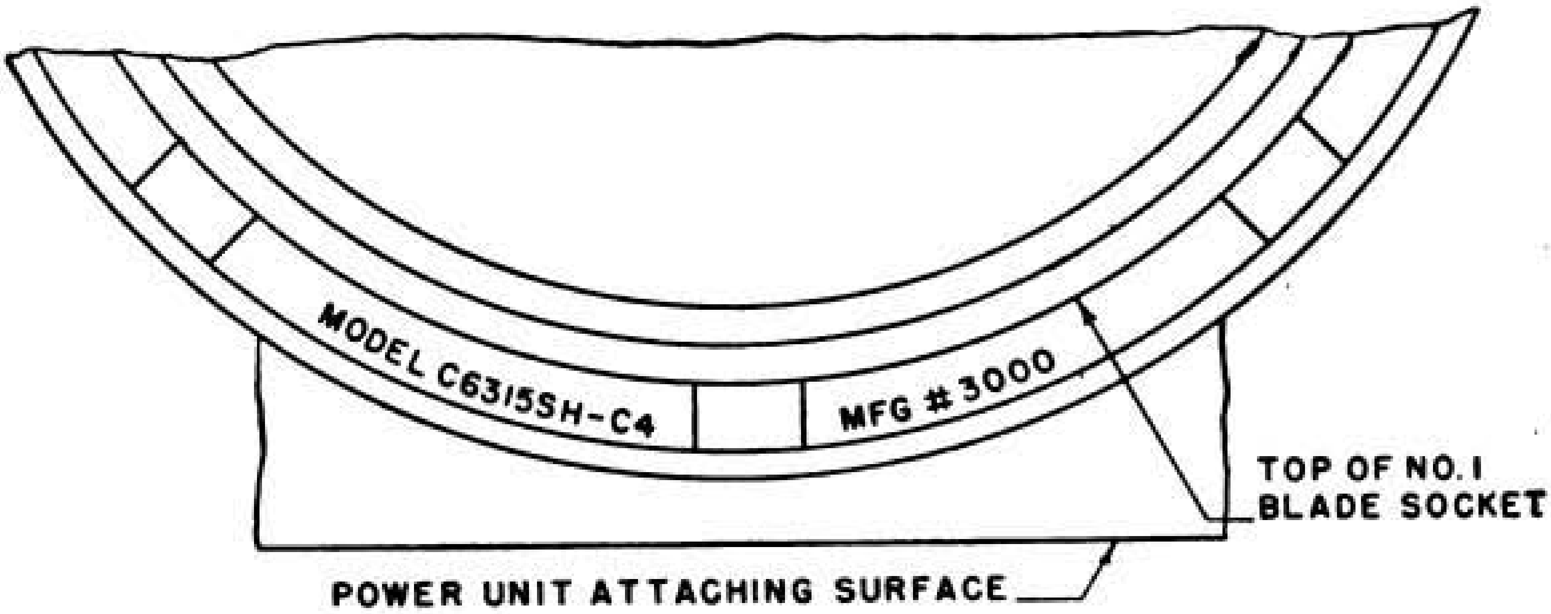


FIGURE 76.—Identification markings on a Curtiss electric propeller.

tery. This motor, through a series of gears, drives a power gear that in turn meshes with a gear attached to the shank of each blade. The electric motor, reduction gears, and power gear are part of a compact unit called the power unit, which is mounted on the front face of the hub.

(1) Some means of completing the electrical circuit from the airplane power supply cut to the pitch-changing mechanism or power unit of the rotating propeller is necessary. This is provided by passing the electric current from the power supply to brushes mounted on the nose of the engine. These brushes ride on bronze slip rings, mounted on the rear part of the hub, which rotate with the propeller assembly. The current is thus transferred from the nonrotating engine nose to the rotating propeller assembly. It is then carried from the rear part of the hub to the front face by means of brass rods extending through the hub. These rods make contact with the power unit, which is mounted on the front face of the hub. The current is then carried to the pitch-changing electric motor by electrical leads in the power unit. The circuit is completed from the motor to the battery by the electrical leads, brass rods, slip rings, and brushes on the engine nose (fig. 77).

(2) Independent electrical circuits may be completed so that the reversible electric motor may be made to rotate in either direction, clockwise or counterclockwise. The power gear will thus rotate in either direction, causing the blades to change to a higher or lower angle, which in turn will decrease or increase the engine rpm.

b. Automatic and manual control.—The electrical circuits may be completed either manually or automatically. Automatic control is provided by a governor. This governor will automatically complete the increase-rpm. or the decrease-rpm. electrical circuit

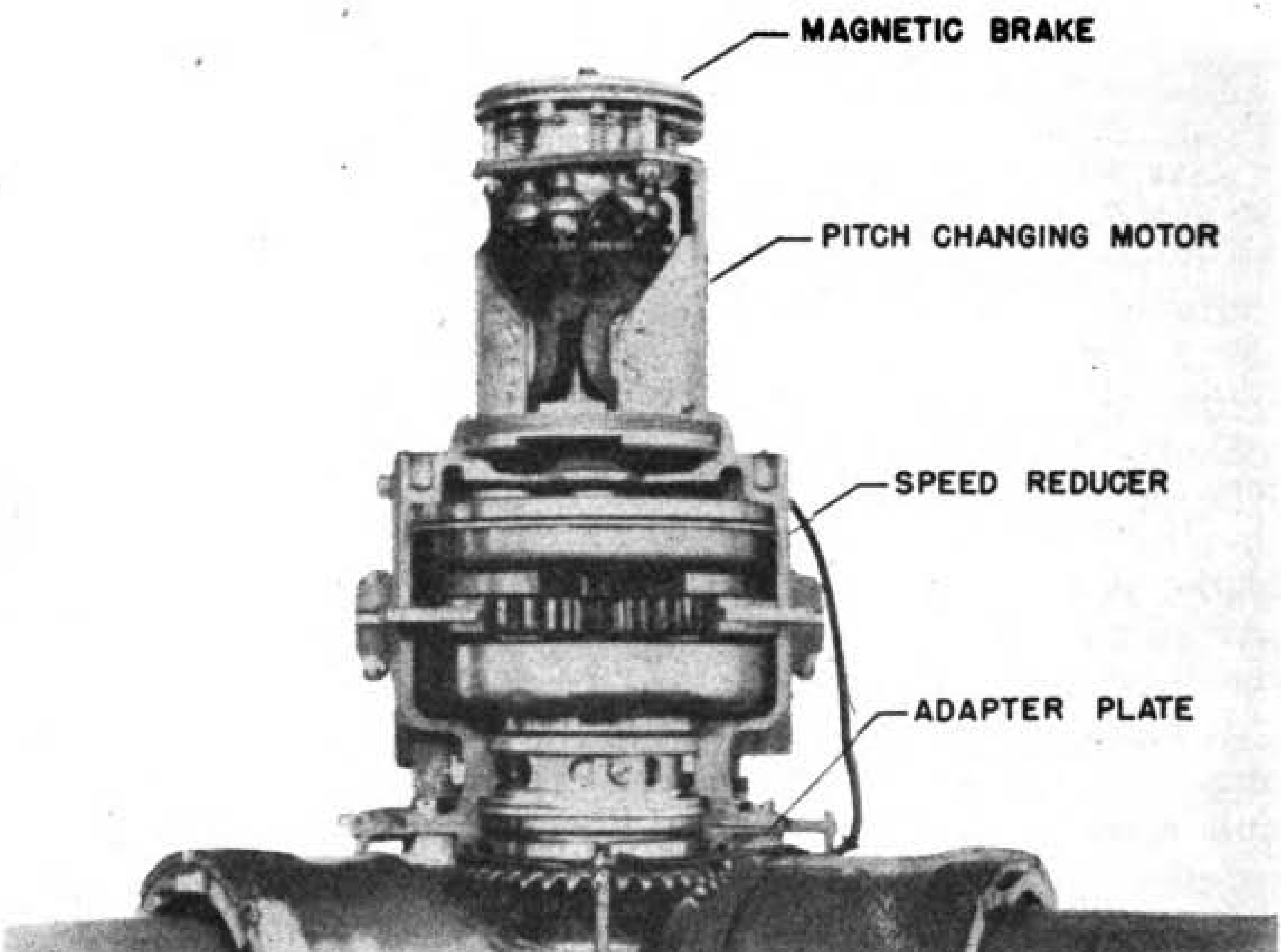


FIGURE 77.—Cutaway of the propeller assembly of the three-blade (conventional) model.

as required to maintain the engine at a constant speed without demanding the attention of the pilot. To change the blade angle, however, he may operate the propeller pitch-changing mechanism manually by completing the electrical circuits for increasing or decreasing the engine rpm. In this second type of control, the propeller acts as a fixed-pitch propeller, except that the pitch desired at any particular moment may be selected; therefore the manual control is called the selective fixed-pitch control. The circuits are so connected that the propeller pitch-changing mechanism may be operated by the remaining control should one system fail. Furthermore, each type of control has its particular advantages for different types of flight operations.

c. Types of governors.—Two types of governors are used with Curtiss electric propellers. One type operates mechanically to complete electrical circuits as required. This type of governor is designed to be mounted on either the engine or the gear box, and is lubricated through the base by means of an integral pump that supplies lubricant from the engine or the gear box. This type is the Curtiss lubricated-pad governor. A second type of Curtiss governor operates both hydraulically and mechanically to complete the electrical circuits. This is the proportional type governor. It is designed to be mounted on the governor drive pad of the engine, and is more extensively used than the lubricated-pad type.

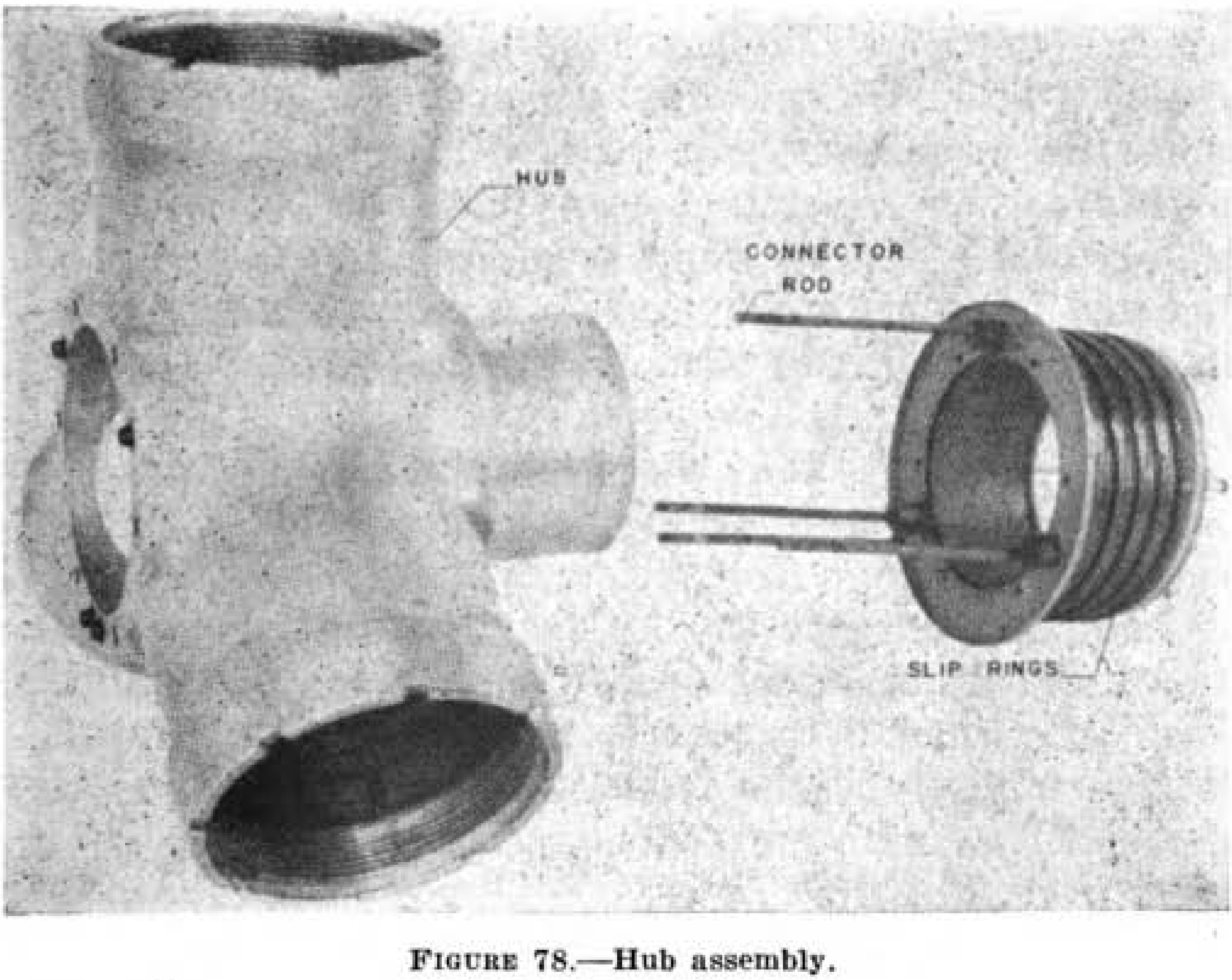


FIGURE 78.—Hub assembly.

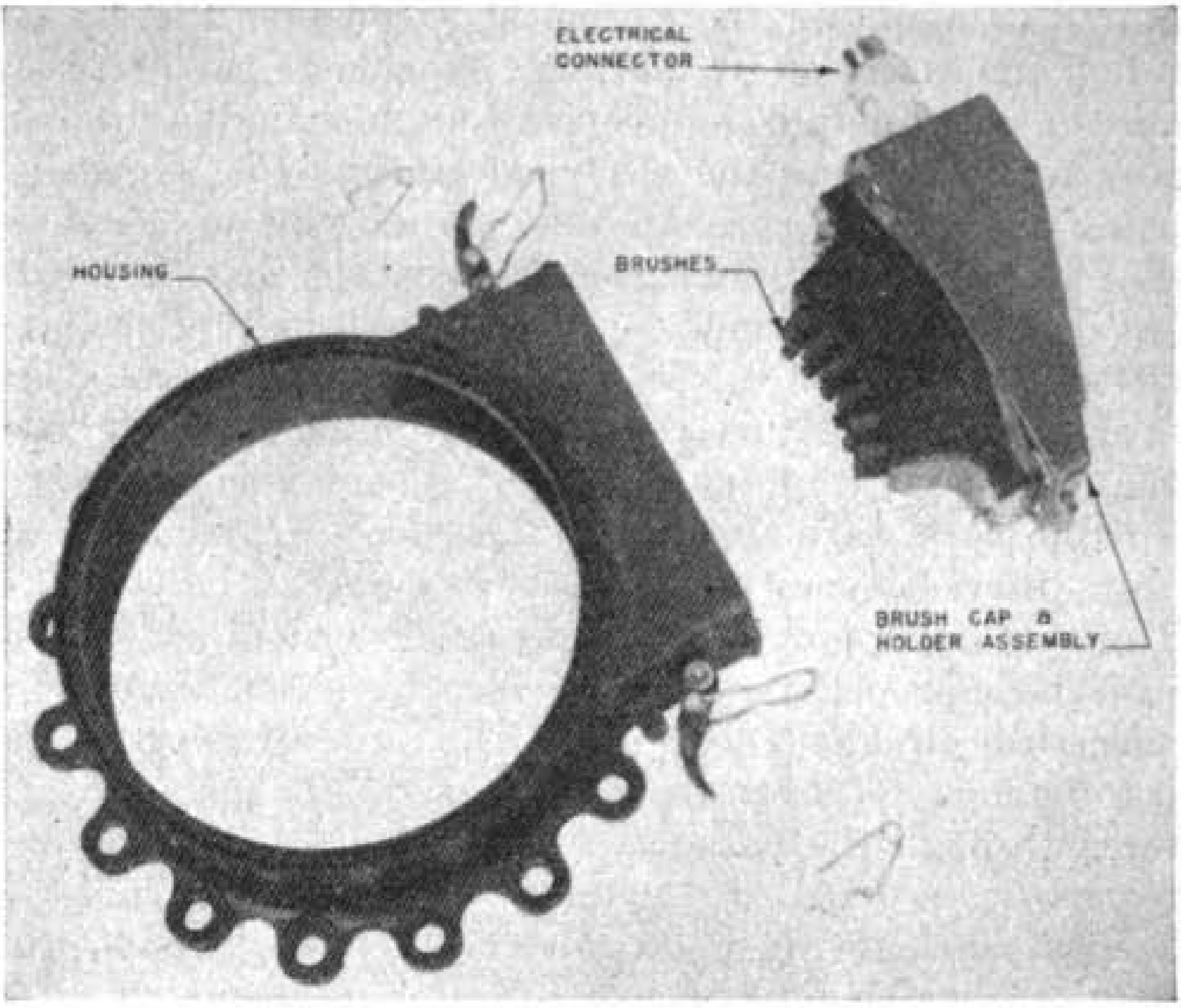


FIGURE 79.—Brush-cap and housing assemblies.

These governors are described in detail in paragraphs 50 and 51.

49. Description.—The Curtiss electric three-blade (conventional) model propeller will be considered in three major parts, the hub, the blades, and the power unit.

a. Hub.—The hub (fig. 78) transmits the powerful engine torque to the propeller blades and withstands the tremendous forces that act on a rotating propeller. The centrifugal force exerted by the blades may be as much as 70 to 80 tons, and the twisting and bending forces are of a lesser magnitude. The hub must be strongly built to withstand the great stresses exerted by these forces.

(1) *Hub structure.*—The hub, which is machined from a single, solid forging of alloy steel, weighs between 50 and 60 pounds. The forging is bored through the center and splined to fit the propeller shaft. Cone seats are machined at the front and rear. The three sockets are bored out simultaneously and threaded to receive the blade retaining nuts. A groove to receive the snap ring is machined in the hub, and the front face is tapped to receive the power-unit bolts. An anti-icer slinger ring assembly can be incorporated as a part of the hub assembly.

(2) *Slip rings.*—The bronze slip rings that receive the electri-

cal current from the brushes are mounted on the rear of the hub, and rotate with the propeller assembly. These slip rings are separated from the hub and from each other by bakelite insulators. An insulated brass connector rod is attached to each slip ring to carry the electrical circuit from the slip rings through passages in the hub to contacts at the front face of the hub. In installations that have four rings, three rings carry the current for the feathering, increase-rpm, and decrease-rpm electrical circuits respectively; the fourth slip ring is the common ground through which the three electrical circuits are completed. From fore to aft, or from the rear of the hub to the nose of the engine, the slip rings are placed in this order: feathering, common ground, increase-rpm, decrease-rpm. Some single-engine installations have only three slip rings, the feathering slip ring being eliminated.

(3) *Brush holder and housing.*—The brushes that ride on the slip rings are mounted in a holder, and the holder is mounted in an aluminum-alloy housing bolted to the nose section of the airplane. The brushes riding on the slip rings transmit the current from the airplane power supply to the rotating propeller assembly. The brush cap is held to the housing by means of trunk type latches. These, and the safety-pin safetying device, make possible quick mounting and removal of the brush cap. Two to six brushes riding on each slip ring give a positive contact and provide a safety margin (fig. 79).

b. Blades.—(1) *Hollow steel blades.*—The hollow steel blades are made by welding together two formed sheets of alloy steel. The shank and camber plate are formed from one sheet, and the thrust plate from another. These two sheets are welded together along the leading and trailing edges in seams that meet at the shank and extend to the root end of the blade. The hollow steel blade thus formed has a straight shank. The blade retaining nut and a stack of antifriction bearings fit around this cylindrical straight shank. Each stack of bearings is manufactured as a unit and individual bearings of a stack must be kept together. These bearings are so constructed that tightening of the blade retaining nut will expand the outer races of the bearings against the hub socket and contract the inner races around the blade, thus assuring a rigid blade assembly. The inside of the cylindrical shank is threaded to receive a spiral bevel gear, which is held firmly to the blade by means of a pin that extends through the shank and into the gear. A blade-gear plug is fitted into the end of the blade

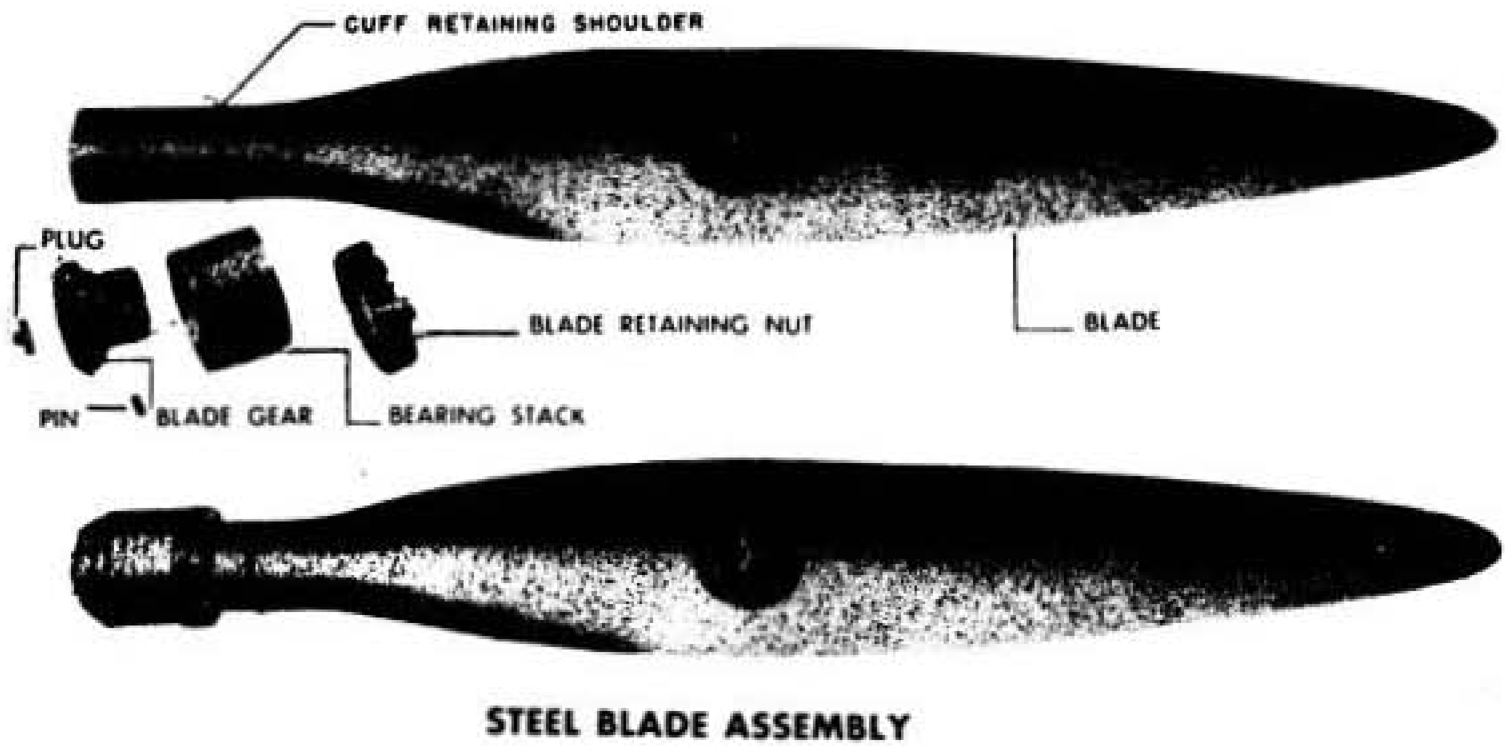


FIGURE 80.—Steel blade assembly.

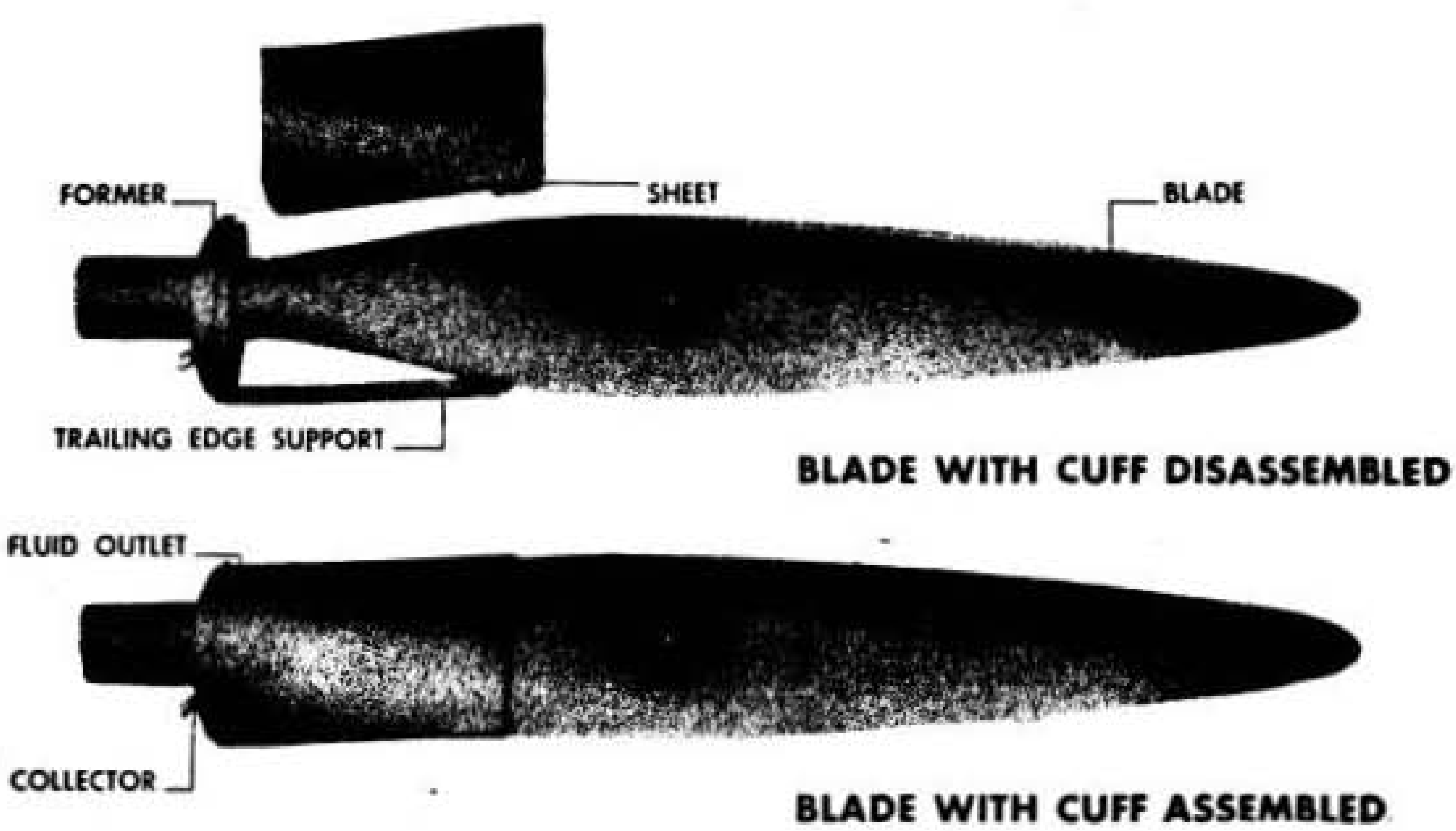


FIGURE 81.—Blade and cuff assembly.

gear to prevent grease in the hub from being thrown out into the hollow blade (fig. 80).

(2) *Blade retention.*—When the blade is inserted in the hub and the blade retaining nut is threaded into place, the back of the blade gear acts as a shoulder on the blade to retain it in the hub.

(3) *Blade cuffs.*—Because the shanks of hollow steel-propeller blades are made cylindrical and deliver no thrust, difficulty is sometimes encountered in cooling radial air-cooled engines. To remedy this difficulty, blade shank cuffs (fig. 81) are designed. They are attached to the shank of the blade and carry the airfoil to the hub. The airfoil increases the airflow to the engine and thus provides better cooling. Cuffs also reduce drag and improve the airflow around the fuselage and wings of the airplane. The cuff consists of a cast-magnesium support and a stiffener, to which a formed sheet made of metal (aluminum), is attached by screws. The entire cuff assembly is held in position by a small shoulder built as an integral part of the blade. (fig. 80).

(4) *Aluminum-alloy blades.*—The aluminum-alloy blades of the Curtiss electric propeller are machined from a forging of high-grade aluminum alloy. The blade root is shaped to accommodate

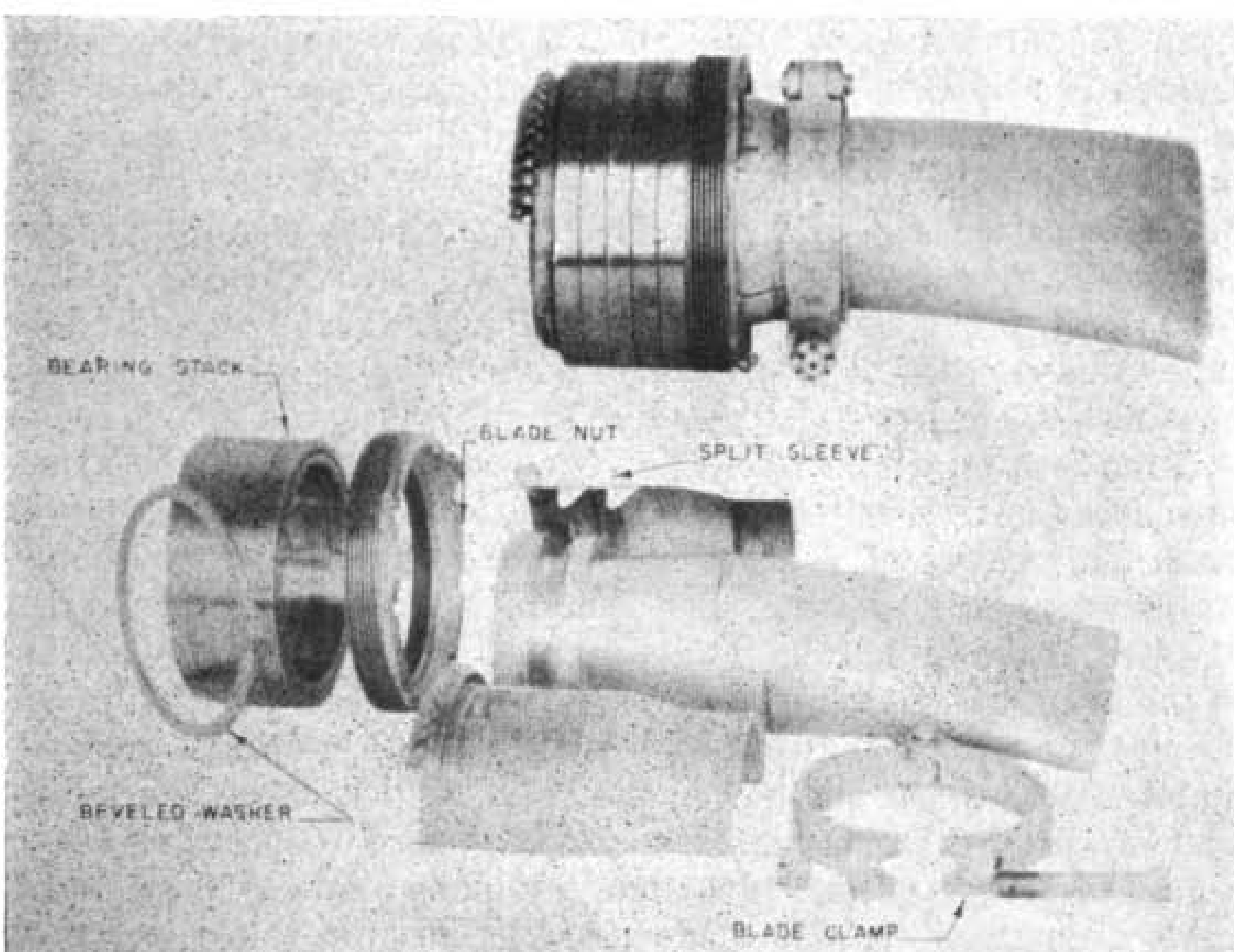


FIGURE 82.—Aluminum-alloy blade assembly.

a split steel sleeve which is clamped to it. Bevel-gear teeth are machined on the end of one of the halves of the split sleeve to form the blade gear. A blade retaining nut, beveled washer, and a stack of bearings placed on the split steel sleeve complete the assembly (fig. 82).

c. Power unit.—The electrical pitch-changing mechanism of the Curtiss electric propeller is contained in one compact unit called the power unit (fig. 83) which is attached to the front face of the hub by means of bolts. The power unit consists of four main assemblies: the pitch-changing motor, the speed reducer, the power gear, and the magnetic brake. Each assembly has its own special function, but all four assemblies are combined into one compact unit which has the important function of producing a blade-angle change when an electrical circuit is closed either by the action of the governor or by manual control.

(1) *Pitch-changing motor.*—The pitch-changing electric motor (fig. 84①) is a series-wound d-c motor operating from the airplane power supply. There are two field windings in the motor to provide for rotation in either direction (fig. 84②). As current passes through one of the field windings, it sets up a magnetic field, and the armature operating in this field rotates in a clockwise direction. On the other hand, when the current is cut off from the first field winding and is passed through the other (which is wound in the opposite direction), a new magnetic field is set up in which the poles are reversed. The armature operating in this field will rotate in a counterclockwise direction. In normal flight operation, the armature shaft of the pitch-changing motor rotates at speeds ranging from 2,250 to 3,000 rpm. For faster feathering, provision is made so that the shaft will rotate at four times this speed. The pitch-changing motor is mounted in a steel housing attached to the front speed-reducer housing.

(2) *Speed-reducer assembly.*—The rotary motion of the armature shaft is transmitted through a series of gears to the power gear. This series of gears is called the speed-reducer assembly. As its name implies, the speed reducer accomplishes a reduction of speed at the same time that it is transmitting the rotary motion of the armature shaft to the power gear. The total reduction in one power unit is such that every time the armature rotates approximately 9,000 times, the power gear rotates just once. The reduction of speed thus accomplished by the speed reducer results in a gain of torque needed to change the blade angle. A finer blade-angle adjustment is also made possible, because the power gear moves a very small fraction of one rotation whenever the arma-

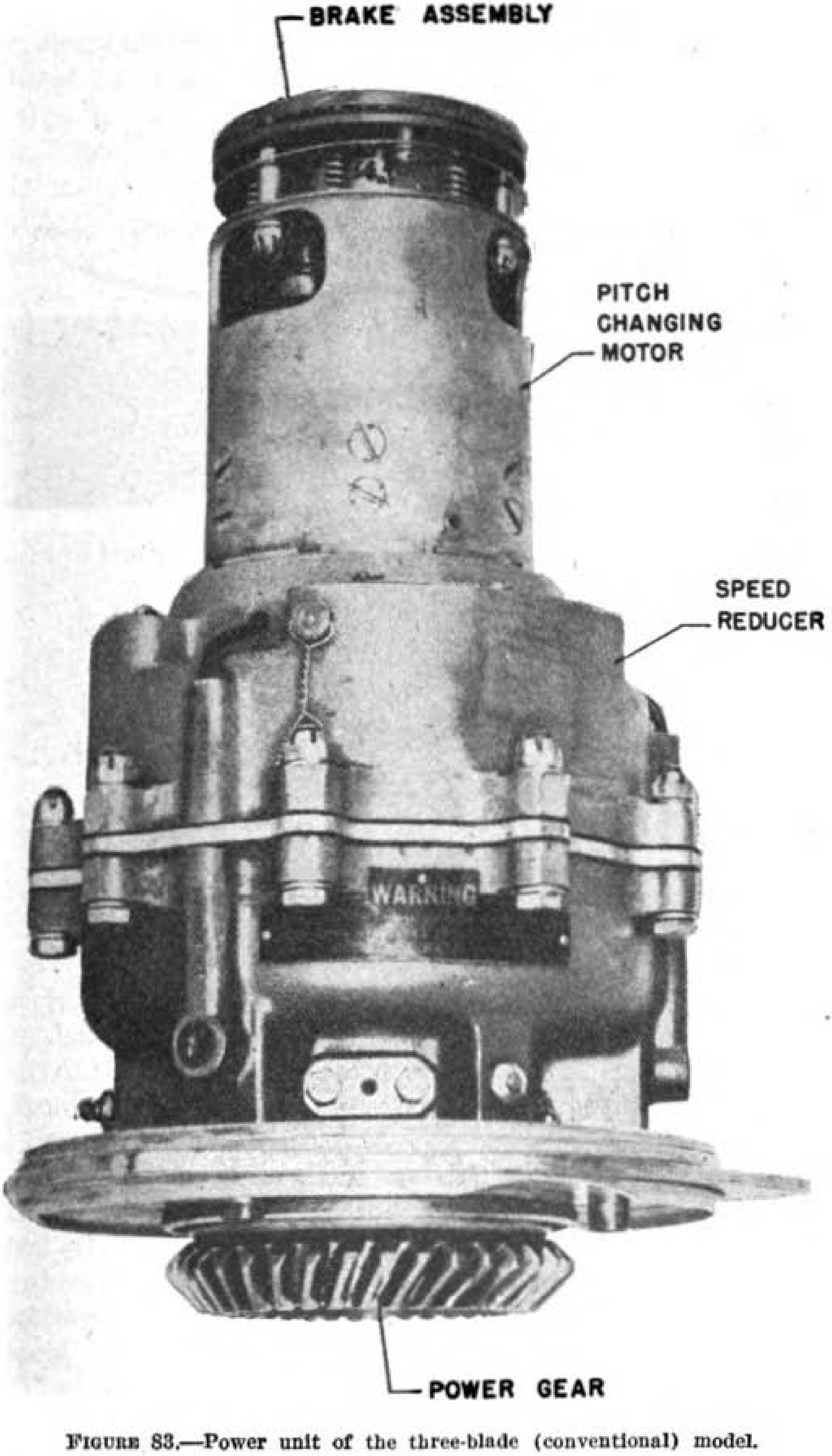
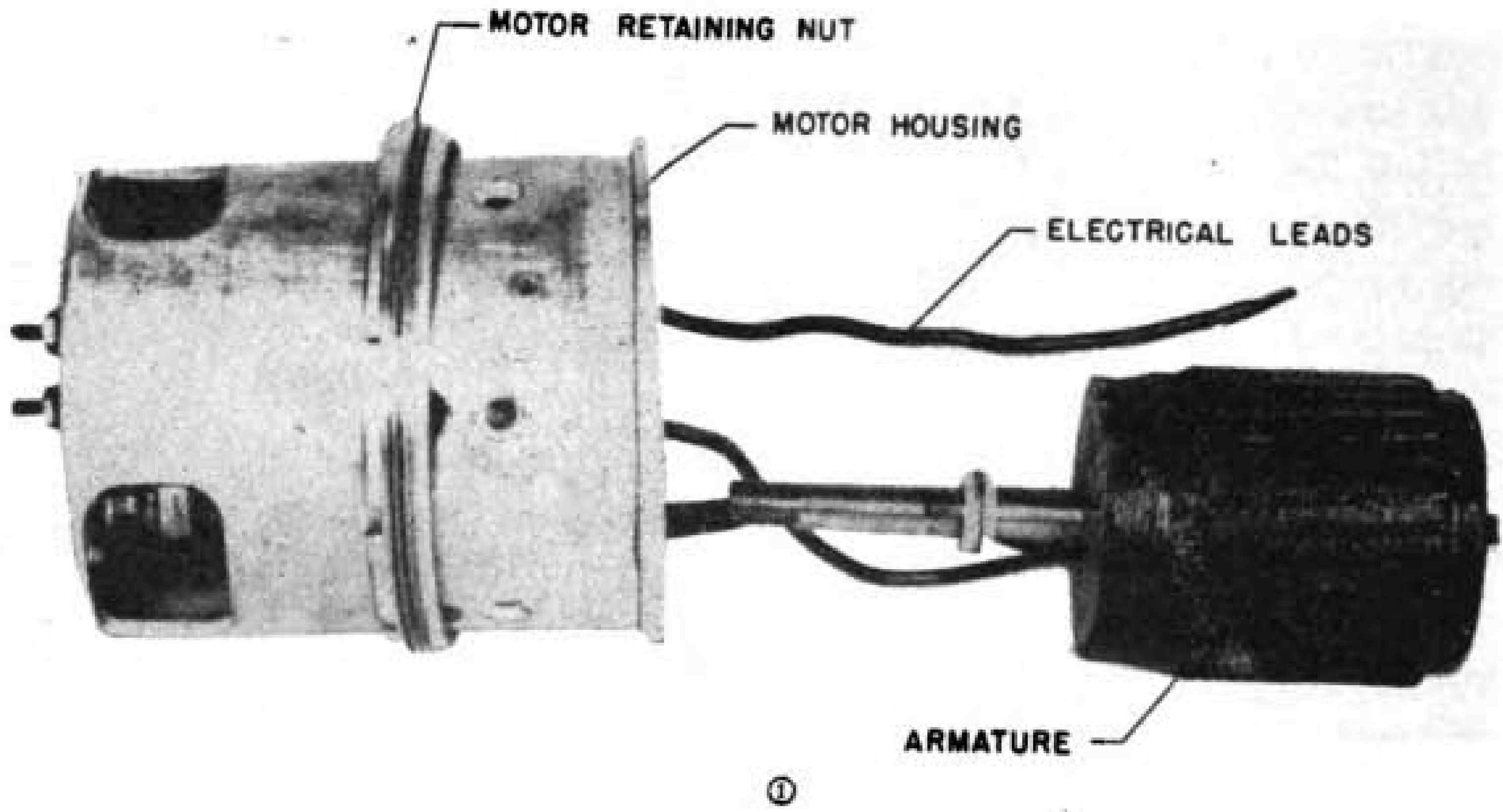


FIGURE 83.—Power unit of the three-blade (conventional) model.



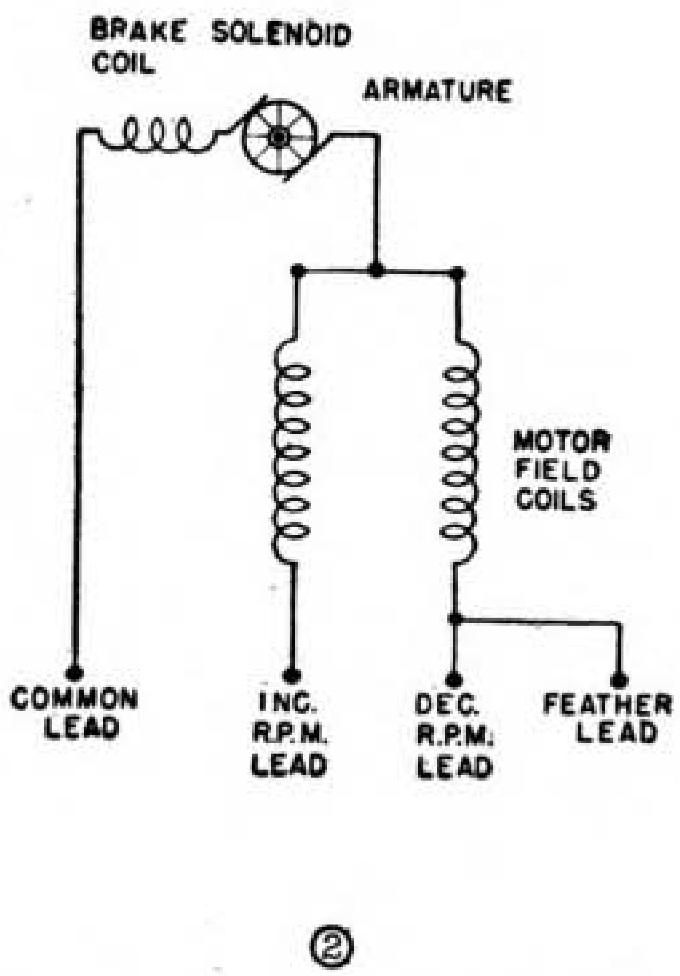


FIGURE 84.—Pitch-changing motor, and wiring diagram.

ture shaft rotates once. The speed reducer of the power unit is built in two stages of planetary-type gearing mounted in an aluminum-alloy housing (fig. 85). The gears are fitted with ball bearings, and the entire unit is made oiltight by seals and gaskets. Running on ball bearings, and operating in light oil, the speed reducer functions with maximum efficiency.

(3) *Automatic limit switches.*—Automatic limit switches are subassemblies of the speed-reducer assembly. They are designed to halt the pitch change at the low, high, and feather blade-angle settings. These switches, mounted in the hub end of the speed

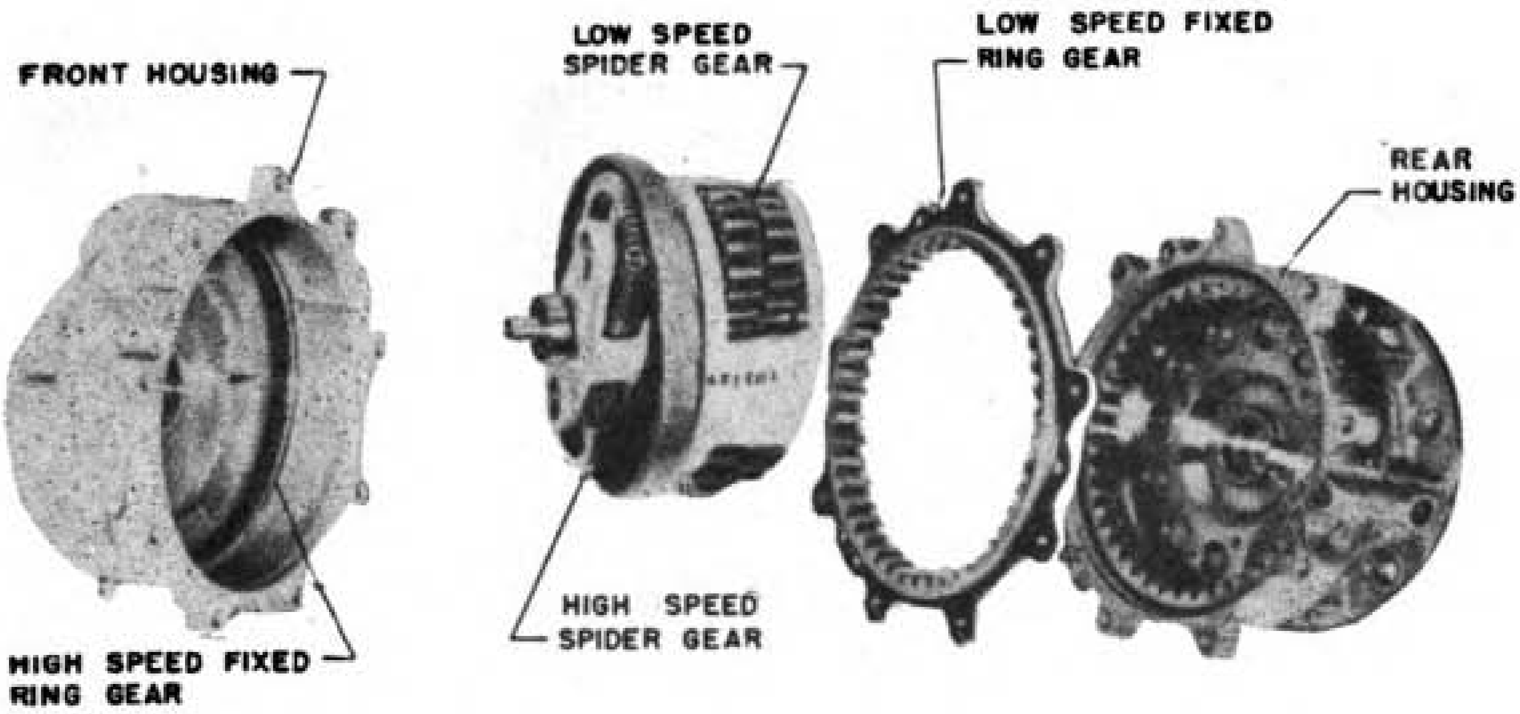
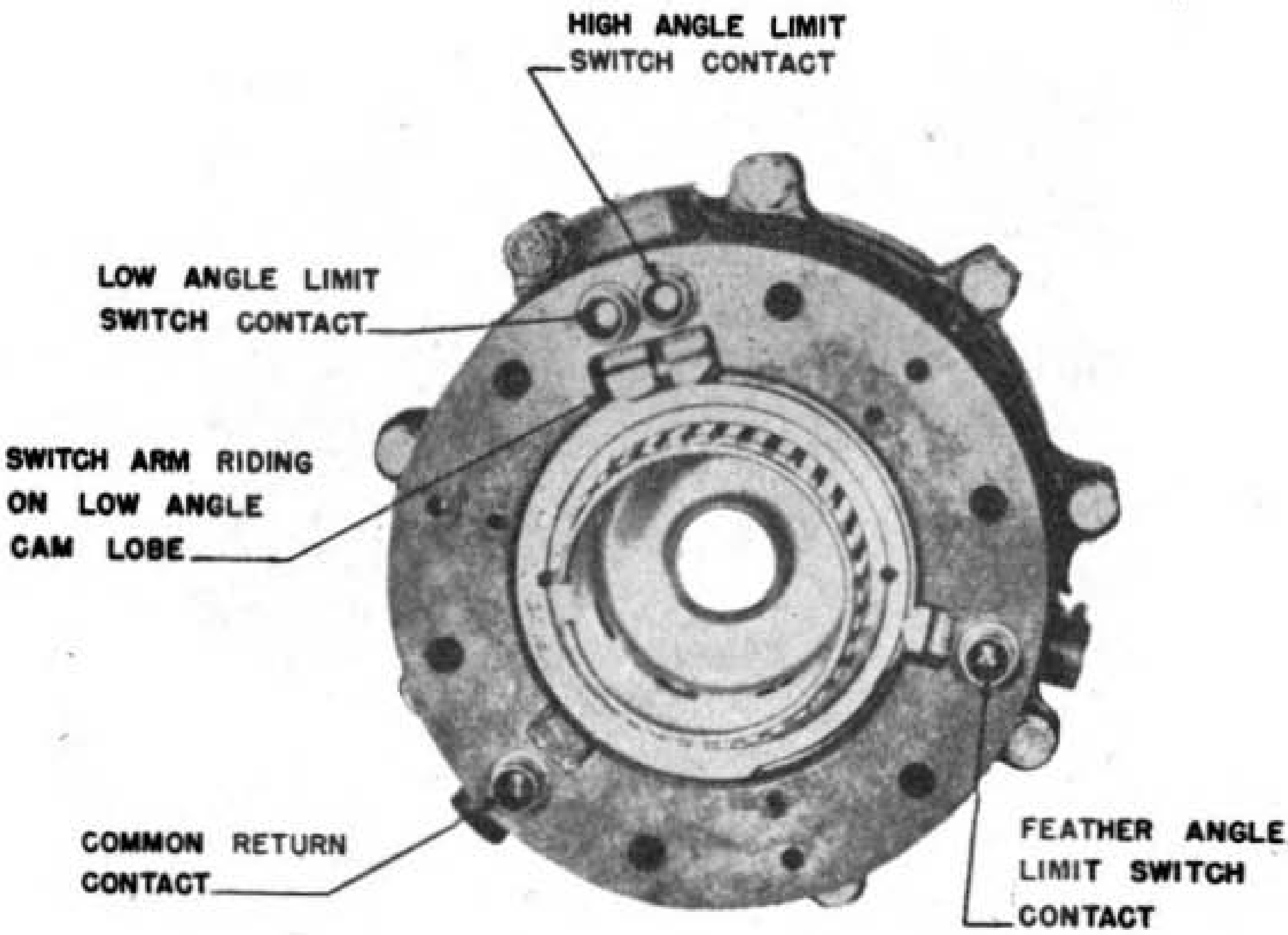


FIGURE 85.—Speed-reducer assembly.

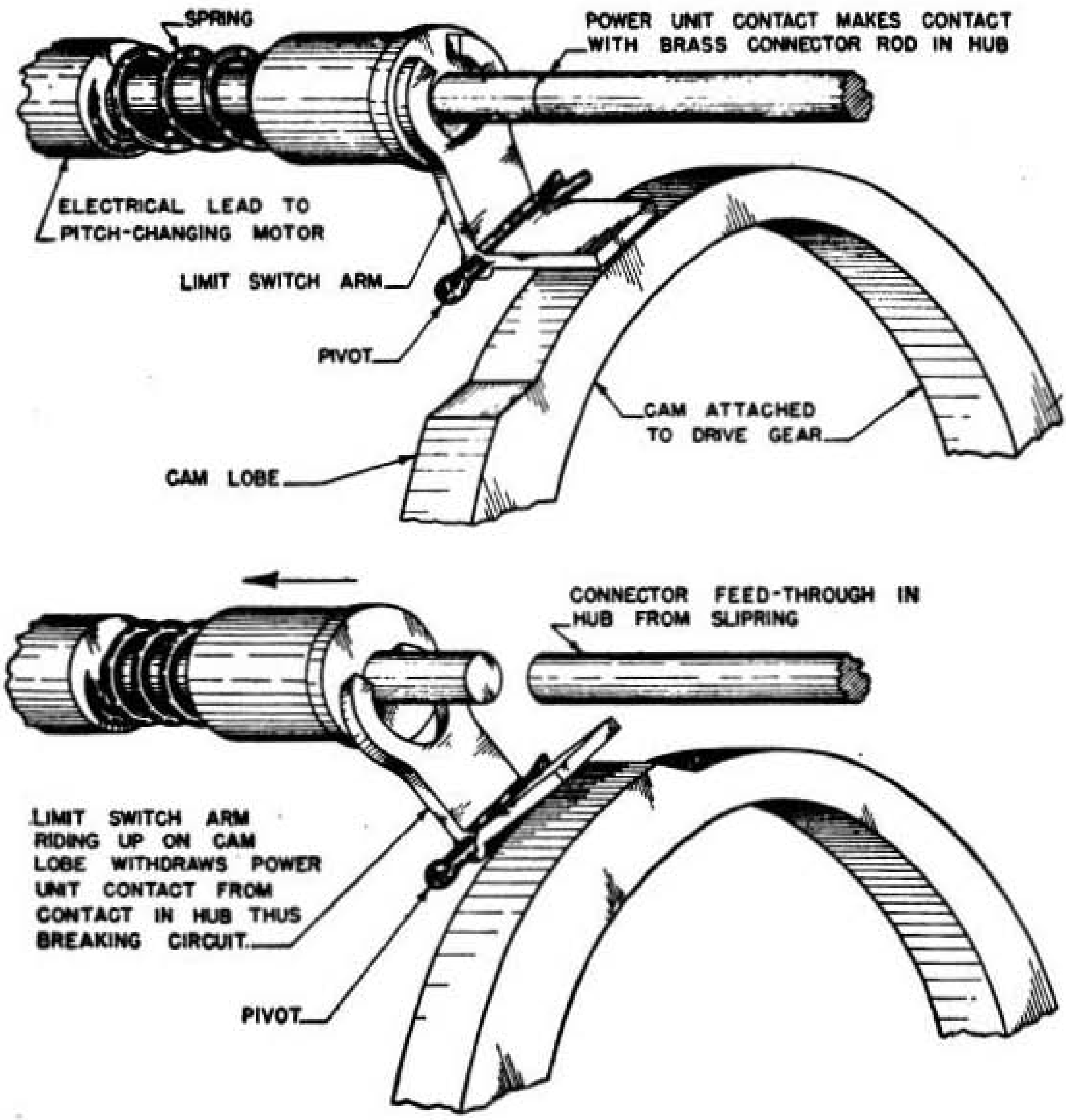
reducer, are connected to the electric-motor leads. They are spring-loaded electrical contacts, which upon installation of the power unit, mate with fixed contacts (brass connector rods) on the front face of the hub (fig. 86①). The limit switches are operated by pivot arms which ride on a cam. This cam, a metal ring, is attached to the main drive gear of the speed reducer, the gear to which the power gear splines. Should the pilot or the automatic control attempt to turn the blades to a lower or higher angle than the propeller is set for, the pivot arms will ride up on their respective cam lobes and withdraw the spring-loaded electrical contacts from the fixed contacts in the hub (fig. 86②). The electric circuit is then broken and the pitch change halted. The feathering limit switch operates in a similar manner, the same cam being used to stop the blade in the feathering position.



(R. H. PROPELLER)

① Location.

FIGURE 86.—Limit switches.



③ Operation.

FIGURE 86.—Limit switches—Continued.

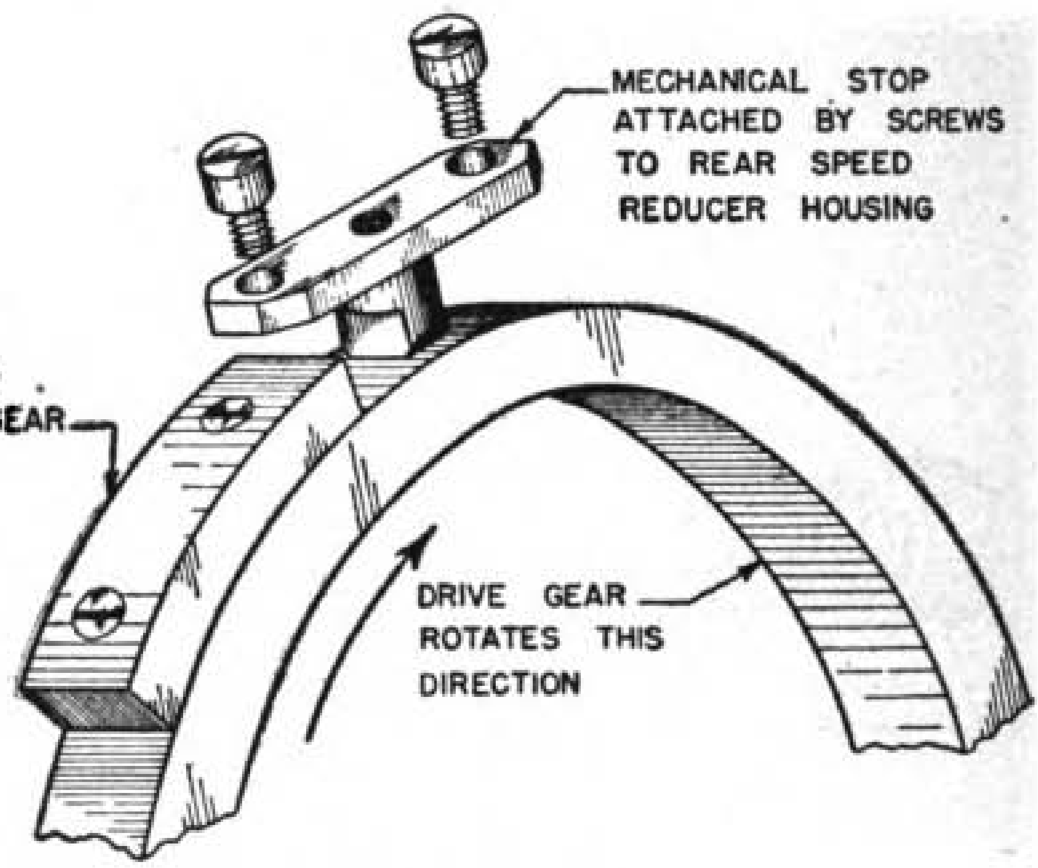


FIGURE 87.—Operation of the mechanical stop.

(4) *Mechanical stop assembly.*—Another subassembly of the speed-reducer is the mechanical stop (fig. 87). This consists of a steel stop segment and a steel mechanical stop plug. The segment is attached to the main drive gear of the speed reducer. The steel mechanical stop plug extends through a hole in the rear housing of the speed reducer and is held in place by two screws. In the event of any mechanical failure that leaves the blades free to rotate, centrifugal twisting moment on the blades will carry them toward low pitch. From 1.2° to 2° below the point at which the low-limit electrical switch normally cuts out, the stop segment will strike the mechanical stop plug and prevent the blades from going to a lower pitch. Overspeeding and complete failure of the engine is thus prevented. ***Caution:*** Whenever it is found necessary

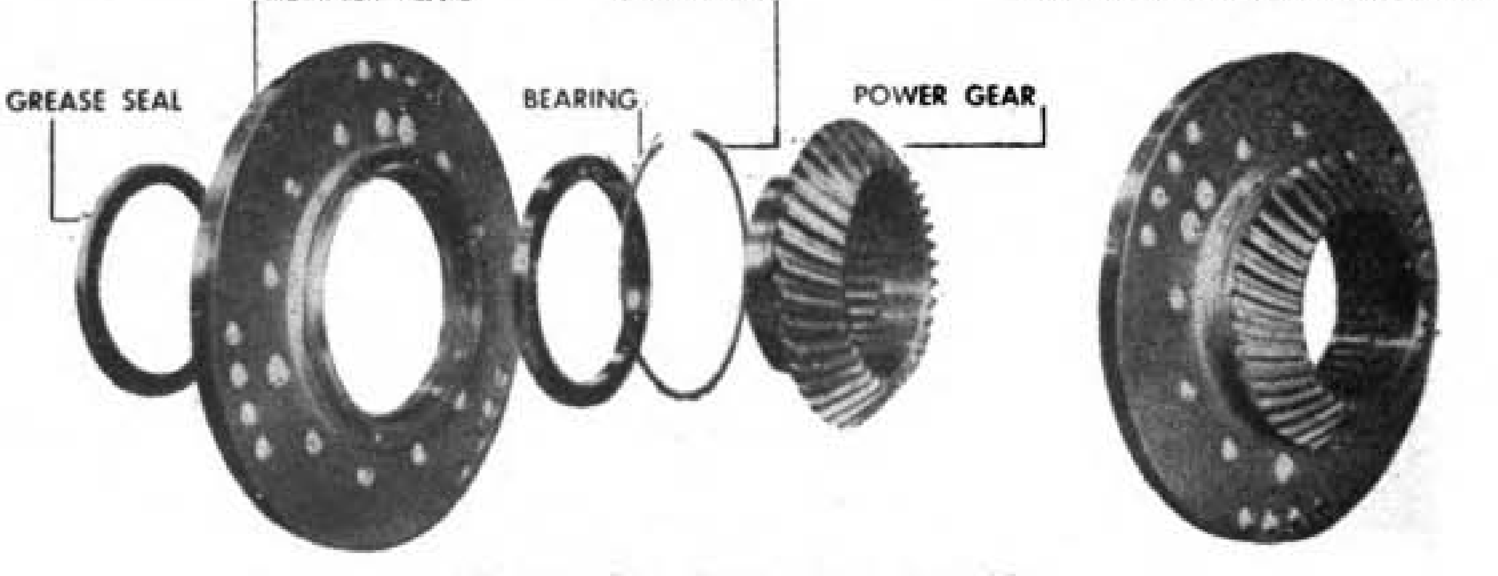


FIGURE 88.—Power-gear assembly.

to operate the power unit independently of the hub (in this case the operation of the limit switches will be ineffective) it is very important that the mechanical stop plug first be removed from the rear speed-reducer housing. This is necessary to eliminate the possibility of damaging the aluminum housing.

(5) *Power-gear assembly.*—The last gear in the speed reducer is called the drive gear. It is to this gear that the power gear (fig. 88) is splined. When the power unit is mounted on the front face of the hub, the power gear meshes with the blade gears, so that the rotary motion produced by the electric motor is transmitted to the blades, thus changing the blade angle. This power gear is equipped with a thrust bearing and both gear and bearing are mounted in a steel adapter plate. The adapter plate seats the

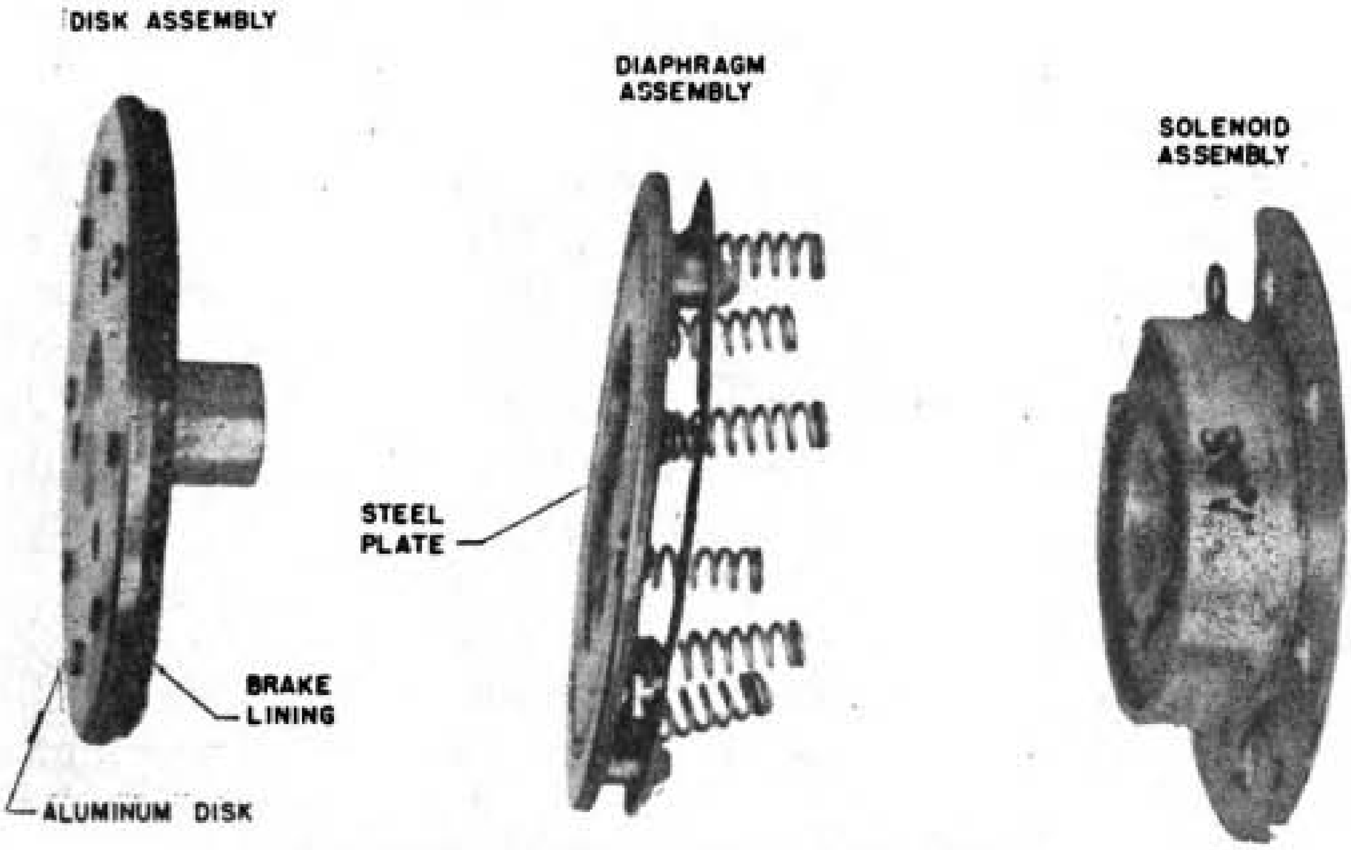


FIGURE 89.—Brake assembly, expanded view.

power unit to the hub, so that the power-gear teeth mesh properly with the blade-gear teeth. The plate serves also as a mounting for the propeller spinner, if one is used.

(6) *Magnetic-brake assembly.*—The brake of the pitch-changing motor must operate in such a way that it will disengage at the instant the electrical circuit to the motor is completed, and, as the electrical circuit to the motor is broken, will reengage to stop the armature shaft from rotating. The magnetic brake operates in exactly this manner. When the pitch-changing motor is operating, the electric current that runs the motor also energizes a solenoid which is connected in series with the motor armature (fig. 84②). The magnetic field thus created releases

the brake. The moment the electrical circuit to the motor and the solenoid is broken, the magnetic field no longer exists. The brake is then applied by coil springs behind the plate.

(7) *Construction of magnetic brake assembly.*—In the diaphragm type brake, the solenoid is attached to the pitch-changing motor housing. In front of the solenoid and supported by a diaphragm is the steel brake plate. The aluminum brake disk (to which a brake lining is fastened) is keyed to the forward end of the armature shaft, which extends through a hole in the center of the brake plate. The coil springs that hold the brake plate against the brake disk are compressed between the plate and the motor housing (fig. 89). The moment the electrical circuit to the pitch-changing motor is broken the brake is engaged by the springs, thus preventing coasting or creeping of the armature shaft and change of blade angle. The splined disk-type brake consists of a fixed thrust plate assembly, a splined hub which is keyed to the motor shaft, a splined-disk brake facing, a rear brake-plate assembly, a brake solenoid coil (mounted behind the rear brake plate) and three springs. The external splines of the hub engage the internal splines of the brake facing, which therefore "floats" between the thrust plate and the rear plate. When the motor is operated, the solenoid (which is connected in series with the motor) is energized and the brake is released. When the motor is not operating, the solenoid is not energized and the brake is applied by the springs.

50. Lubricated-pad governor.—*a. Description.*—(1) The lubricated-pad governor consists of two major assemblies, an upper and a lower (or base) case (fig. 90). Both are aluminum-alloy castings.

(2) The spindle shaft extends through the lower case of the

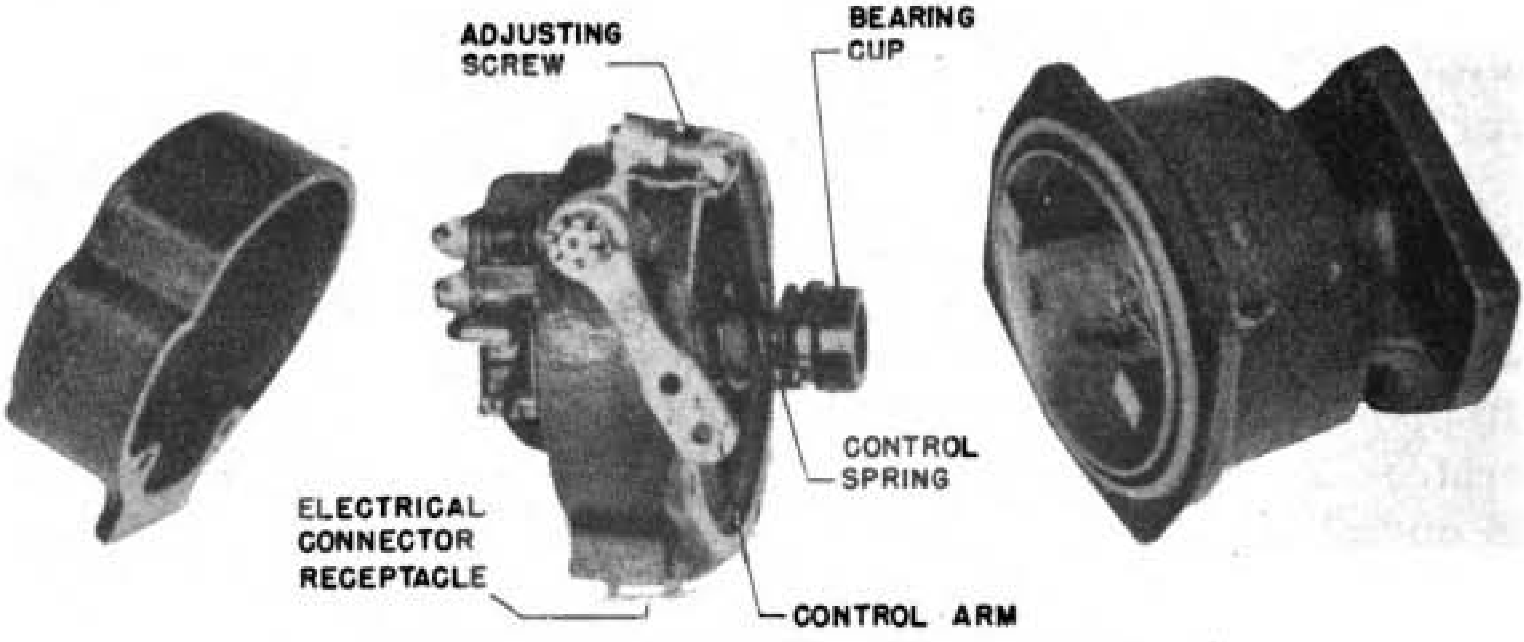


FIGURE 90.—Curtiss lubricated-pad governor.

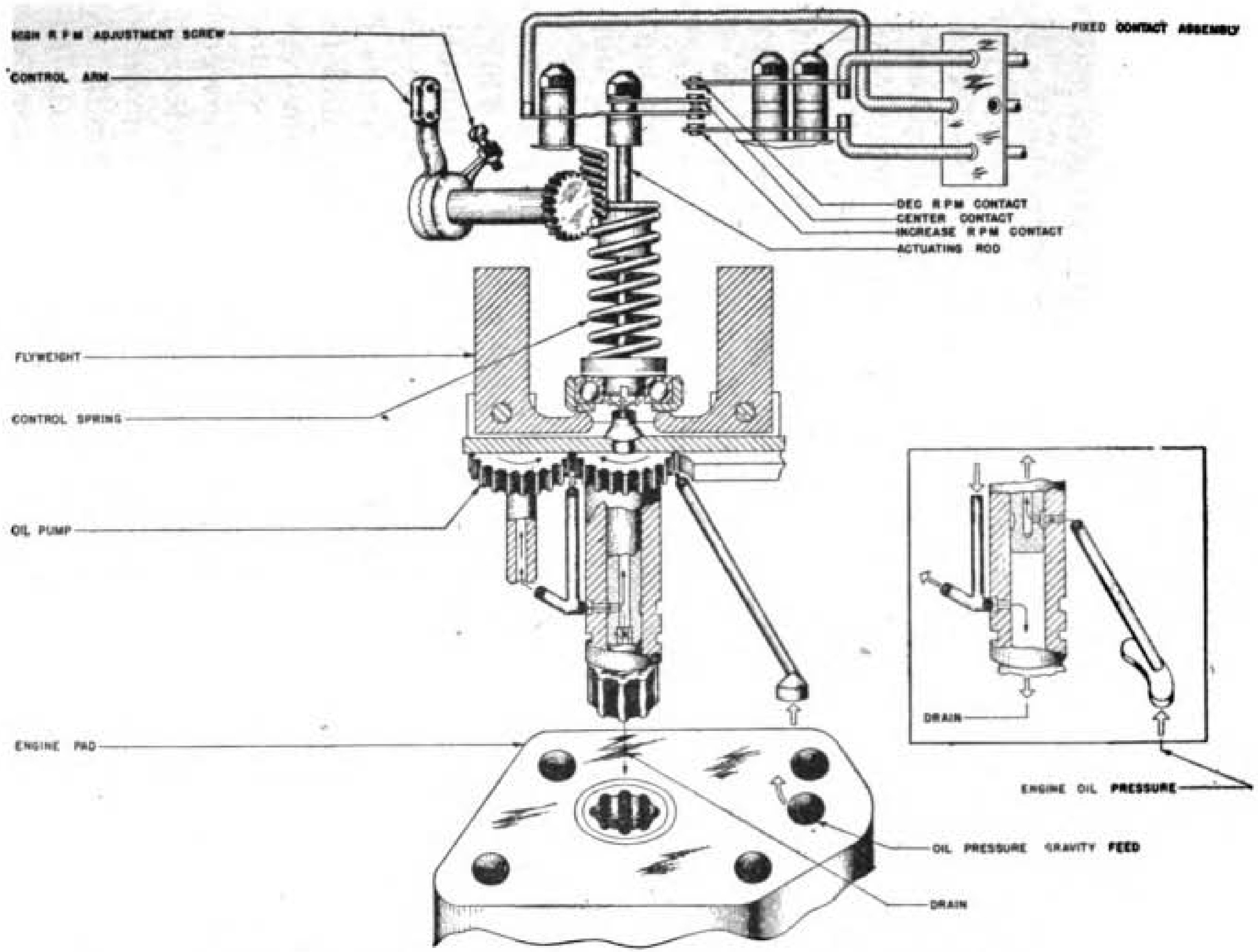


FIGURE 91.—Schematic diagram of the Curtiss lubricated-pad governor.

governor. When the governor is mounted on the mounting pad of the engine or gear box, the splined lower end of the spindle shaft engages a standard governor drive from the engine or from the engine-to-propeller reduction gears. At its upper end, this spindle supports the flyweights. An aluminum bell is placed around them to minimize churning of the oil. The drive gear of the oil pump is pinned to the upper end of the spindle shaft, just beneath the flyweight assembly. This gear meshes with the idler pump gear, which is mounted in the lower case. The governor oil pump circulates lubricating oil from the engine or gear box to the bearings and gears of the governor, and prevents the governor case from becoming excessively filled with oil (see fig. 91).

(3) An rpm control which makes it possible for the pilot to vary the compression of the control spring is mounted in the upper case. A control shaft extending through the upper case is fitted at its outer end with a control arm. The governor cockpit control is connected to this control arm by means of a mechanical linkage actuated by control cables or push-pull rods. Backward or forward movement of the cockpit control will cause a like movement of the control arm. This movement will rotate the control shaft and a pinion gear fitted to its inner end. The pinion gear meshes with a spring block which bears against the upper end of the governor control spring. The rotary motion of the pinion gear will cause the spring block to move up or down, decreasing or increasing the compression of the spring. This arrangement makes it possible for the pilot to vary the compression of the control spring. An adjustable take-off-rpm stop is also fitted to the outer end of the control shaft. This stop limits the travel of the control arm in the increase-rpm direction, and thus limits the extent to which the control spring can be compressed (fig. 91).

(4) In order that electrical connections between the governor and the propeller circuits may be made easily, an electrical connector receptacle is attached to the upper case of the governor. Three wires are required to complete the governor circuit. One wire is the power line and it is connected, by means of the electrical connector plug and receptacle, to the center contact in the governor. The other two wires are connected to the increase-rpm and decrease-rpm fixed contacts mounted in the upper case on either side of the movable center contact. The center-contact assembly is made up of two separate contact points. It is connected to an actuating rod which extends through the control spring

and supports the spring at one end, the spring block supporting the spring at the other end. This actuating rod rests on a bearing, and the lobes of the flyweight rest against this bearing. Thus, any movement of the flyweights under centrifugal force causes a corresponding movement of the movable contacts through the mechanical linkage of the actuating rod. The upper case is fitted with a cover to protect the contact mechanism.

b. Principle of operation.—This governor is fundamentally an electrical switch which opens and closes electrical circuits that control the propeller blade angle. Any change in engine rpm will result in a change in the centrifugal force acting on the flyweights. Variations in the centrifugal force acting on them will cause the flyweights to assume different positions. The movement of the flyweights will result in corresponding movements of the actuating rod and the center contact points because of the action of the flyweight lobes directly on the actuating rod bearing.

(1) If the engine rpm increases, the tops of the flyweights move outward under the additional centrifugal forces, causing their lobes to raise the actuating rod and the center contacts. The upper center contact touches the decrease-rpm fixed contact in this case, and the decrease-rpm electrical circuit is completed from the airplane battery to the pitch-changing motor. The blade angle decreases until the flyweights move inward to an upright, "on speed" position, in which case the center contacts are directly between the fixed contacts, and blade-angle change ceases.

(2) If the engine rpm decreases, the spring force will override the centrifugal force on the flyweights and lower the actuating rod and center contacts. Contact is made with the increase-rpm contact to complete the increase-rpm electrical circuit until the engine is brought up to the desired speed. The flyweights then again assume an upright, "on speed" position.

(3) The governor is thus sensitive to variations in engine rpm, and, acting as an electric switch to complete the circuits automatically, it will cause blade-angle changes that will compensate for these variations. Furthermore, the pilot may select different engine rpm by compressing the speeder spring to a greater or a lesser extent. This will cause the flyweights to move inward or outward, so that electrical contact will be made with the increase- or decrease-rpm contact. Higher or lower engine rpm will result, increasing or decreasing the centrifugal force on the flyweights until it exactly balances the spring force.

51. Proportional governor.—Like the lubricated-pad governor, the proportional type governor is essentially an automatic elec-

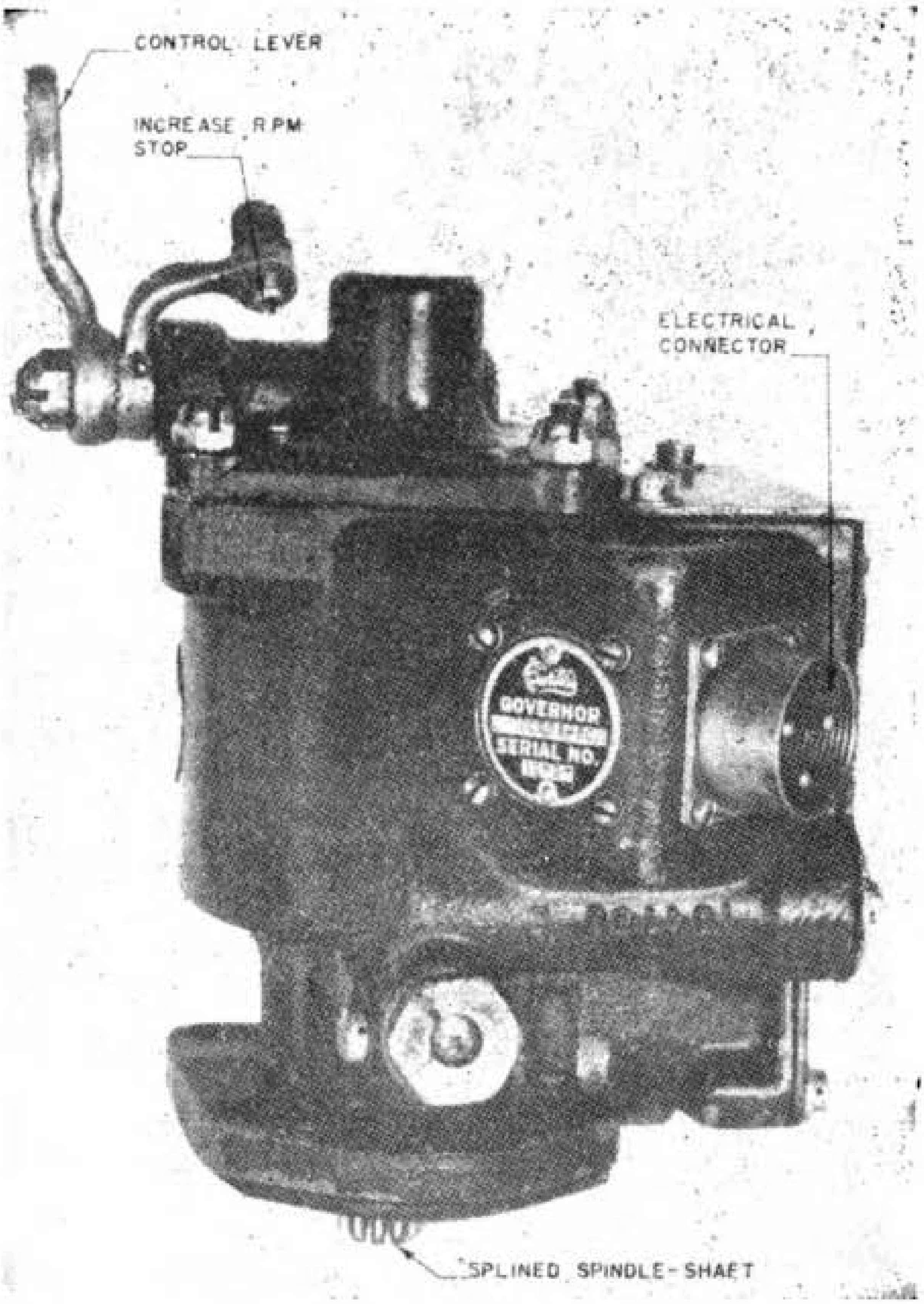


FIGURE 92.—Proportional governor.

tric switch placed in the propeller circuit. However, in place of a direct mechanical linkage from the flyweights to the electrical contact arm, a hydraulic valve and actuating unit are used.

a. Description.—The proportional type governor consists of two major assemblies, the lower case and the upper case. The lower case contains a flyweight spindle-shaft assembly, an oil pump, a relief valve, a scavenger pump, a contact mechanism, and an electrical connector. The upper case houses a rack, control shaft, and lever, which function together to control the compression on the control spring. (fig. 92).

(1) *Flyweight spindle-shaft assembly.*—Mounted in the lower case is the spindle-shaft assembly. The lower end of the spindle shaft is splined to fit the standard governor drive shaft in the engine. The spindle shaft carries the flyweights and the flyweight valve. A small clearance between the shaft and the valve allows a small amount of oil to bypass from the oil supply to lubricate the flyweights and the bearing on which the governor control spring is seated. The flyweights are inclosed in an aluminum shell mounted on top of the spindle shaft. This shell prevents excessive churning of the oil by the flyweights. The flyweight arms are connected to the flyweight valve which slides inside the hollow spindle shaft, so that movement of the flyweights under centrifugal force creates a corresponding movement of the valve in the shaft. The valve design is of the balanced type. Its movements change the inlet and the outlet openings at the same time, thereby regulating the pressure in the servo pressure chamber of the flyweight valve.

(2) *Pressure-pump and relief valve.*—Oil under pressure for the hydraulic system of the governor is supplied by a pressure pump. This pressure pump consists of a drive gear pinned to the lower end of the spindle shaft and a meshing idler gear. These gears are housed in the bottom of the governor case beneath a cover plate. A relief valve is located in one side of the lower housing and consists of a spring-loaded plunger mounted in a steel sleeve. The purpose of the pump and the relief valve is to provide constant oil pressure to the flyweight valve regardless of variations in engine oil pressure.

(3) *Scavenger pump.*—In order to prevent the governor case from becoming excessively filled with oil, a scavenger pump is located at the lower end of the flyweight compartment. This pump consists of a small drive gear pressed on the spindle shaft and meshing with a second small idler gear. Passages are provided so that the excess oil is picked up by the pump and discharged

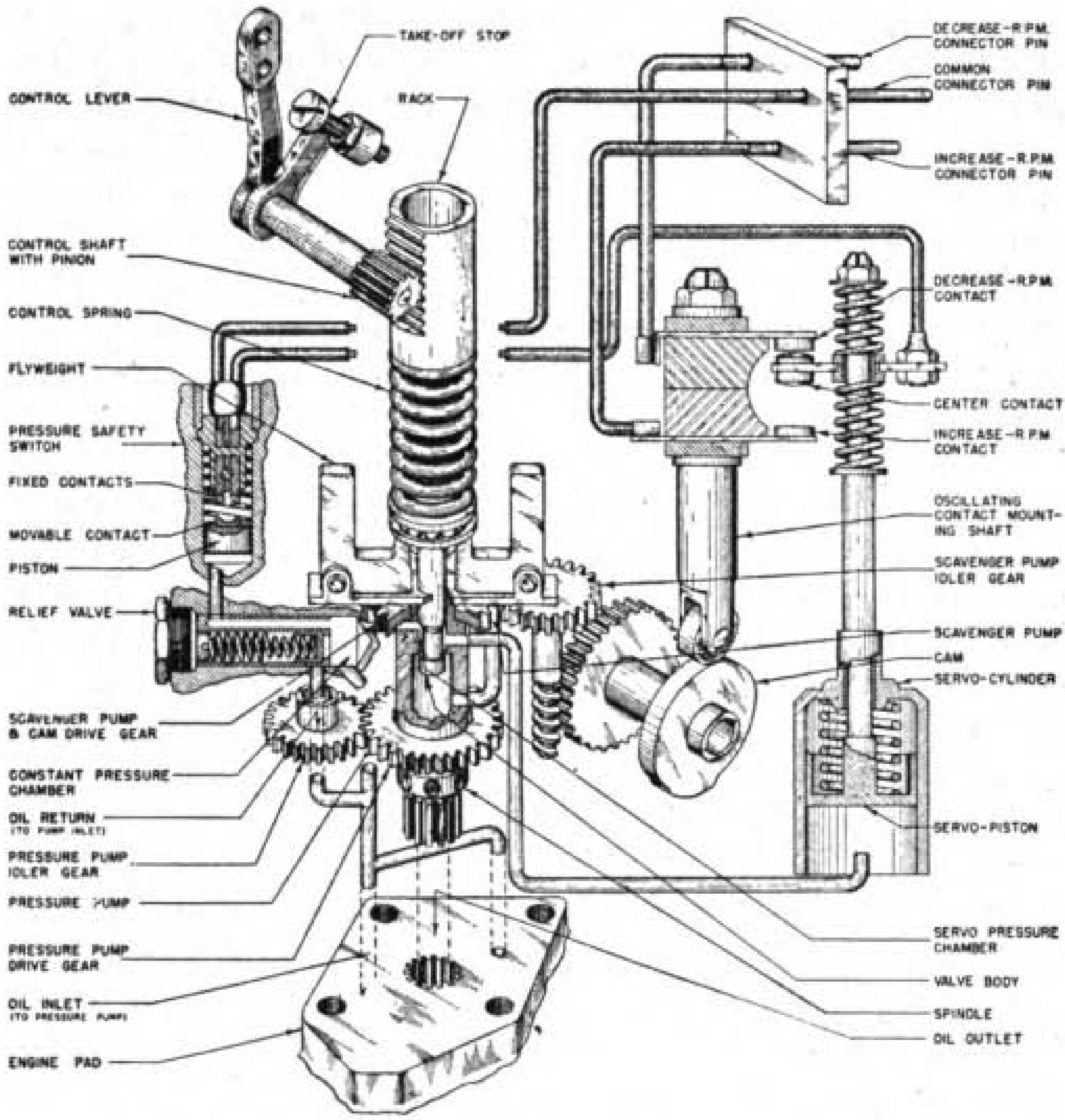


FIGURE 93.—Schematic drawing of the proportional governor.

through the lower portion of the hollow spindle shaft and thus back to the engine. The scavenging system, together with the aluminum shell which incloses the flyweights, enables the governor to operate satisfactorily when mounted in either a horizontal or a vertical position.

(4) *Servo mechanism.*—Changes in oil pressure in the servo pressure chamber of the flyweight valve are transmitted by way of oil passages to a small cylinder mounted in the lower case. In this cylinder a coil spring behind a steel piston serves to counterbalance the oil pressure applied to the piston. An actuating rod, which is an integral part of the piston, extends through the upper end of the servo cylinder and supports the center contact assembly of the switch. The purpose of the piston and cylinder, or servo mechanism, is to move the center switch contact in response to any movement of the flyweights and flyweight valve (fig. 93).

(5) *Pressure safety switch.*—Since the servo mechanism in the

governor would cease to operate if a failure should occur in the engine oil supply, an oil-pressure safety switch is used to automatically disconnect the governor from the propeller circuit. This will cause the propeller blades to remain fixed at the angle they had at the time the oil loss occurred, and remove the possibility of the blades going to positive low pitch because of the oil loss. Opening the automatic control in this manner does not in any way affect the manual-operation control system. The pressure switch consists of two tungsten-tipped contacts placed at one end of a cylindrical hole in the governor base, and of a piston having a mating tungsten contact (fig. 93). The piston with its contact operates in a cylinder. The piston contact is held apart from the mating contacts by a coil spring. The main oil-pressure passage from the relief valve is connected to the switch chamber so that when the oil pressure overcomes the spring pressure, the contacts close the circuit of the power line in the governor from the electrical connector to the center contact. If the selector switch in the cockpit is placed in the automatic position, the power-line circuit will be completed from the airplane battery to the center contact in the governor through the pressure safety switch. Should any excessive drop in oil pressure occur, the pressure safety switch will operate to break the power-line circuit in the governor.

(6) *Governor contacts.*—The governor-switch contact mechanism consists of three tungsten-faced contacts. As already stated, the double-faced center-contact assembly is attached to the servo piston shaft. The decrease-rpm and increase-rpm contacts are rigidly attached to a shaft having at the lower end a roller which rides on a cam driven from the scavenger pump. A coil spring holds the cam follower against the cam so that the contact will continually move up and down, or oscillate, in response to the motion of the cam. This cam arrangement provides greater governor sensitivity and more positive contact. In order that the center contact may follow the movements of the oscillating contacts, it is held in place by a centering spring. This spring permits the contact to slide on the piston shaft when pressure is applied against either face of the contact.

(7) *Electrical connector.*—To facilitate the connections between the governor and the propeller circuit, a connector plug is attached to the side of the lower case. Three wires are required to complete the governor circuit. The power line is connected to the center contact, and wires from the oscillating contacts are connected in the decrease-rpm and increase-rpm circuits of the pitch-control system.

(8) *Upper case assembly.*—The upper case houses a steel rack which is used for controlling the governor rpm. The rack, which operates vertically in the case, bears on the upper end of the control spring. The movements of the rack are regulated by a control shaft with a pinion gear which extends to the outside of the case. A control arm is connected to the outer end of the control shaft. push-pull rods or control cables from the control arm to the cockpit control unit provide an rpm control which makes it possible for the pilot to vary the spring force. A take-off-rpm limit arm having an adjustable stop screw is also pinned to the outer end of the control shaft.

b. Principle of operation.—(1) In the "on speed" condition, the flyweight valve will supply only enough oil pressure to balance the servo piston against its spring, thereby holding the center contact in the OFF or "on speed," position (fig. 93). It is important to note that when the center contact is in this position the two outside contacts, although they are oscillating, do not touch the center contact. There is no completed propeller circuit, so that both the blade angle and engine rpm are constant.

(2) If the engine speed increases slightly, the flyweights will move outward under the additional centrifugal force, and cause the flyweight valve to permit oil under pressure to flow into the servo cylinder. The piston and center contact will move up a small distance toward the decrease-rpm contact, and the center contact will be touched by the upper contact momentarily each time the cam motion brings them together. Thus, for a slight increase in engine speed, the amount of blade-angle correction brought about by momentary contact is sufficient to supply the exact correction for the "off speed" condition. For a greater increase in engine rpm, the center contact will move farther toward the decrease-rpm contact, thereby closing the circuit for a longer period. The length of the periods the contacts remain together increases as the "off speed" condition increases, until finally the two will make continuous contact. Thus, when the "off speed" condition becomes excessive, continuous contact is established. The oscillation of the outer contacts in this manner makes the operation of the governor proportionate to the "off speed" condition.

(3) If the engine speed decreases slightly, the flyweights and flyweight valve will move downward, causing a drop in oil pressure in the servo cylinder. The center contact will move down toward the oscillating increase-rpm contact, and the same action will then result in the increase-rpm propeller circuit as occurred in the decrease-rpm propeller circuit in the case described above.

(4) Other types of governors make a continuous contact for any "off speed" condition however slight, but continuous contact for a slight "off speed" condition tends to cause the blade-angle change to "overrun," and therefore overcompensate, so that it must be changed in the other direction to approach an "on speed" condition. This "hunting" effect is eliminated by the oscillation of the outer contacts, which make a contact in proportion to the amount of "off speed." The positive making and breaking of contact also eliminates much of the arcing (leaping of current between open contacts) which results when the contact is slowly made and broken.

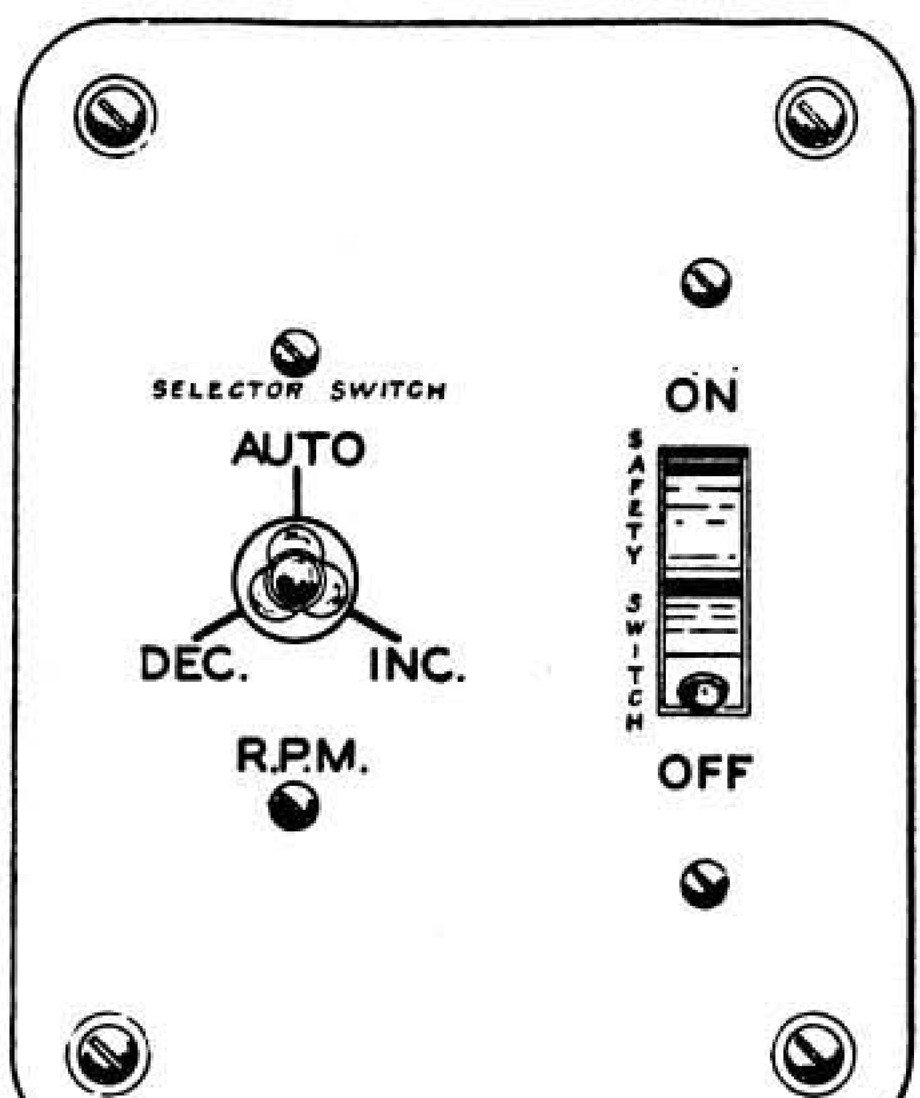
52. **Propeller and governor controls.**—The controls located in the cockpit for completing the propeller electrical circuits as required are the switches and the governor control. By properly operating these switches and the governor control, the pilot may control the propeller pitch change either manually or automatically, and may feather or unfeather the propeller as is necessary. The governor and governor controls are synchronized in the manner described in paragraph 53.

a. Circuit-breaker switch.—The first switch in the wiring system of the Curtiss electric propeller is a thermal circuit-breaker switch known as the safety switch. It is designed to protect the propeller circuit against electrical overloads. Two types of thermal circuit breakers, or thermal safety switches, are in general use on electric propellers: the toggle type and the push-button type. The normal position of the toggle switch is ON; if this switch is opened by an overload, it may be reset again by placing the switch in the full ON position. It may be necessary to repeat this operation more than once before the switch has cooled sufficiently to stay in the ON position. The normal position of the push-button switch is IN. When this switch trips out because of an overload, it may be reset by pushing the button back in. Here again it may be necessary to repeat this operation more than once before the switch has cooled sufficiently to stay in. If the push-button switch should trip out and cannot be immediately reset, it may be bypassed for emergency operation of the propeller by *holding* the button in the full IN position.

b. Selector switch.—When in the ON position, the circuit breaker completes the circuit to the selector switch (in single-engine installations). The selector switch has four positions (fig. 94); OFF, AUTOMATIC, INCREASE RPM, and DECREASE RPM. The purpose of this switch is to select the type of control desired, as well as to provide selective fixed-pitch control. When

the selector switch is placed in the OFF position, the propeller will operate as a fixed-pitch propeller. If placed in the AUTOMATIC position, the circuit is completed to the governor and the pitch change necessary to maintain the engine at a constant speed is chosen automatically (fig. 95). By setting the governor control, the pilot may choose the speed at which he wishes the engine to operate. Manual control is accomplished by holding the selector switch to the increase-rpm or decrease-rpm positions as required, thus completing the circuit to one or the other of the field windings in the pitch-changing motor. The handle is spring-loaded in these two positions, and will spring to the OFF position when released.

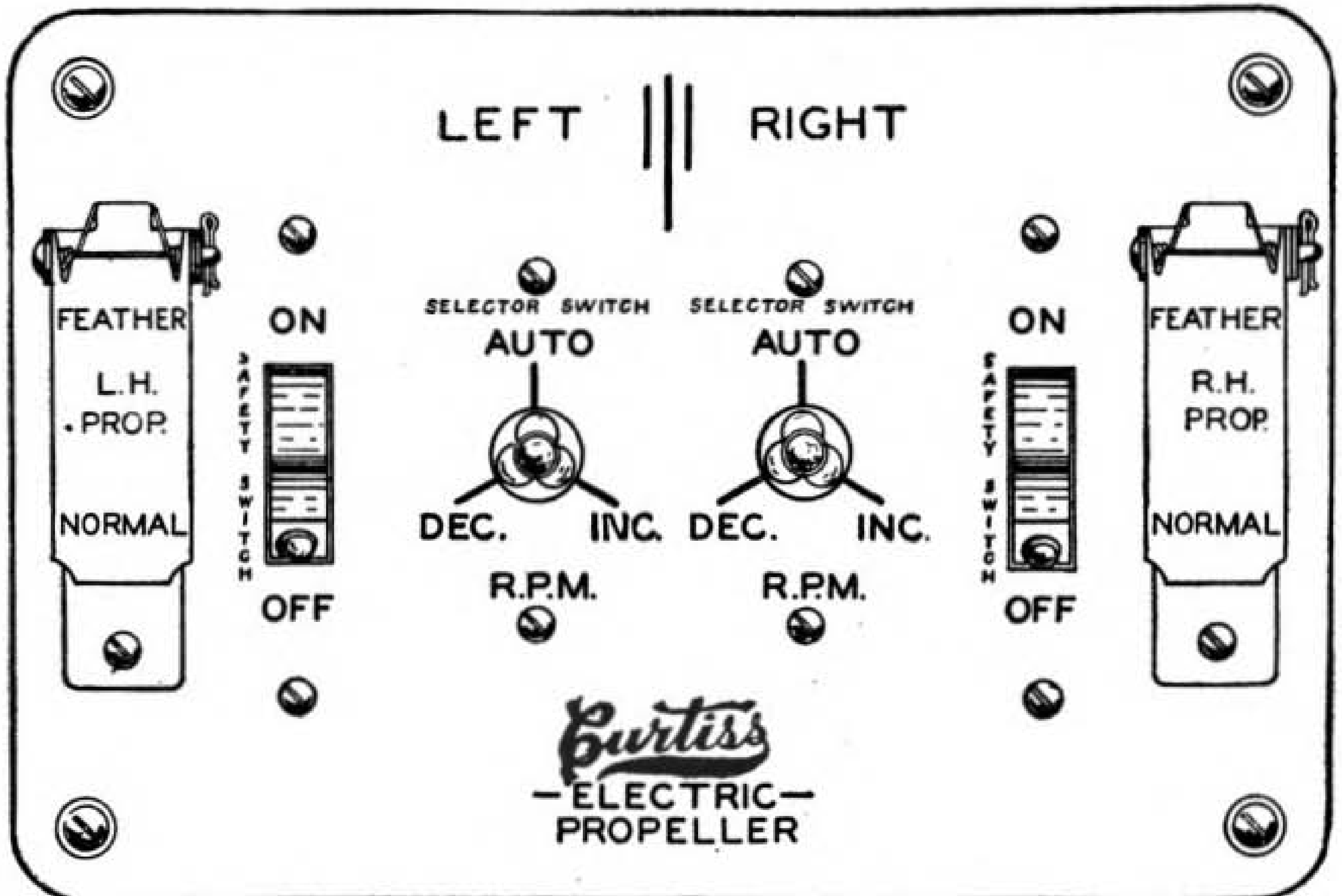
c. Feathering switch.—In multi-engine installations, a feathering switch (fig. 94②) is used for each propeller. The purpose of this switch is to break the normal propeller circuit and at the same time to complete the feathering circuit. It is connected be-



SINGLE-ENGINE SWITCH PANEL

① Single-engine switch panel.

FIGURE 94.—Typical switch panels for Curtiss electric propellers.



TYPICAL TWIN-ENGINE SWITCH PANEL

② Twin-engine switch panel.

FIGURE 94.—Typical switch panels for Curtis electric propellers—Continued.

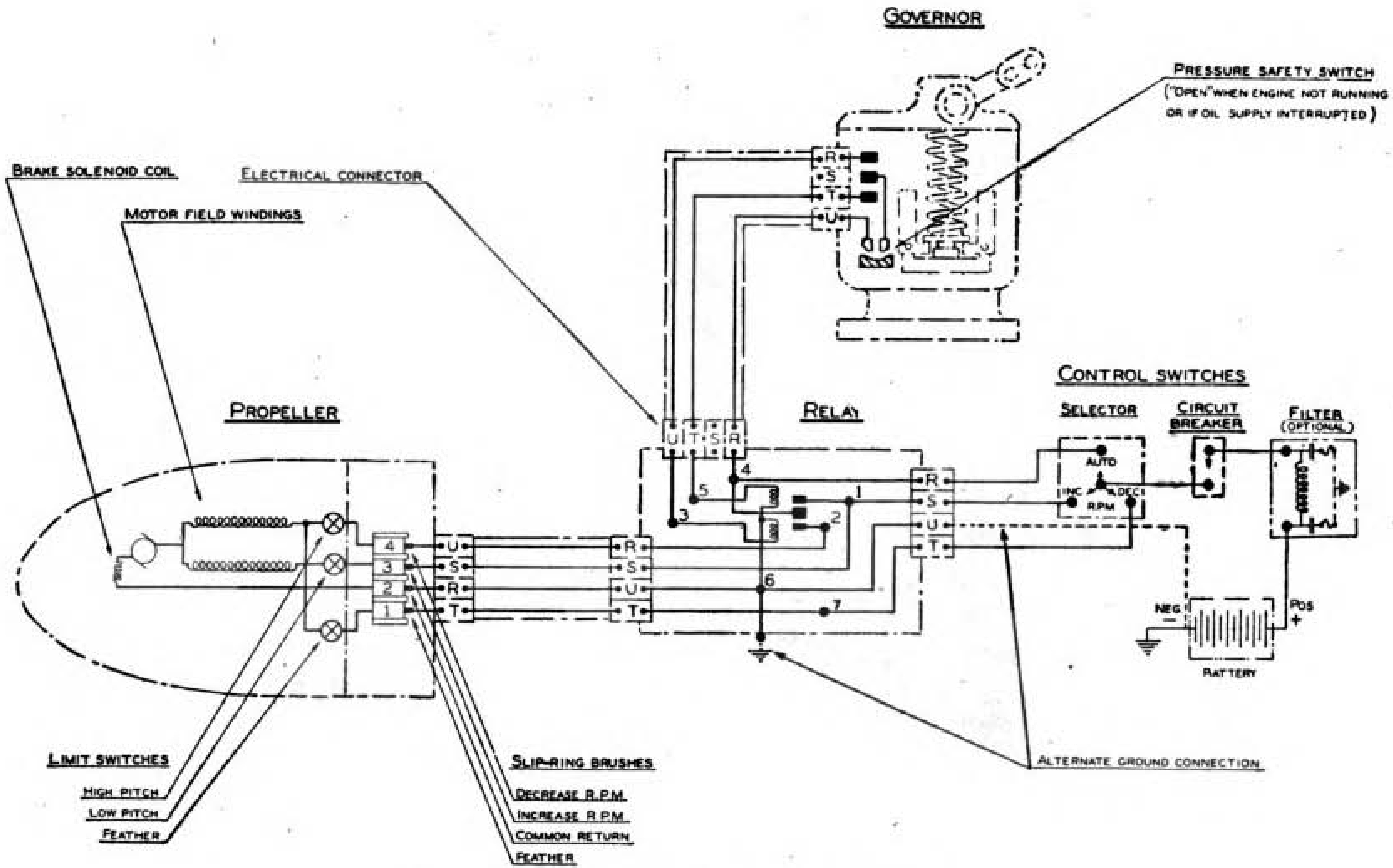


FIGURE 95.—Typical single-engine wiring diagram.

tween the circuit-breaker switch and the selector switch (fig. 96). During all normal propeller operations the switch is placed in the normal position, and in this position it merely completes the circuit from the circuit-breaker switch to the selector switch. In the feather position, it breaks the normal propeller circuit and at the same time completes the feathering circuit. This circuit bypasses both the selector and the safety switch, so that the propeller may be feathered regardless of the position of these switches. A guard is provided to prevent accidental operation of this switch. To unfeather the propeller, the pilot places the selector switch in the manual increase-rpm position.

d. Voltage booster.—For rapid feathering, many installations employ a fast-feathering voltage booster (fig. 96) used only during the feathering operation. This unit is included in the feathering circuit of the propeller control system to multiply the normal voltage to the pitch-changing motor so as to increase the rate of pitch change approximately fourfold. The voltage booster, only one of which is required in each airplane, is a single motor-generator unit. When the feathering circuit is closed, the booster is automatically put into operation. When the blades reach the feather setting, the feather-limit switch in the propeller opens, thereby breaking the feathering circuit.

e. Manual decrease-rpm circuit.—In multi-engine installations, and in single-engine installations using a feathering slip ring, the manual decrease-rpm is connected to the feathering slip ring. If either decrease-rpm circuit is damaged, the other may be used. In multi-engine installations, the propeller may be feathered with the manual decrease-rpm if necessary.

f. Electrical relay.—(1) This relay (fig. 97①) is the heavy-duty switching mechanism of the propeller automatic control circuit. Its purpose is to carry the propeller operating current to the pitch-changing motor while the propeller is operating in automatic control. The relay consists essentially of two solenoid coils and an armature (see fig. 97②). A new relay has a plunger type armature instead of the type shown in the figure. One solenoid is energized by a circuit completed through the governor decrease-rpm contact, and the other is energized by a circuit completed through the governor increase-rpm contact. Whenever the electrical circuit is completed through the governor, one of the relay solenoids is energized and the relay armature is drawn against one or the other of two relay contacts. Since the relay armature is connected in the propeller "power" line, the propeller circuit is thus completed through either the increase-rpm or the decrease-

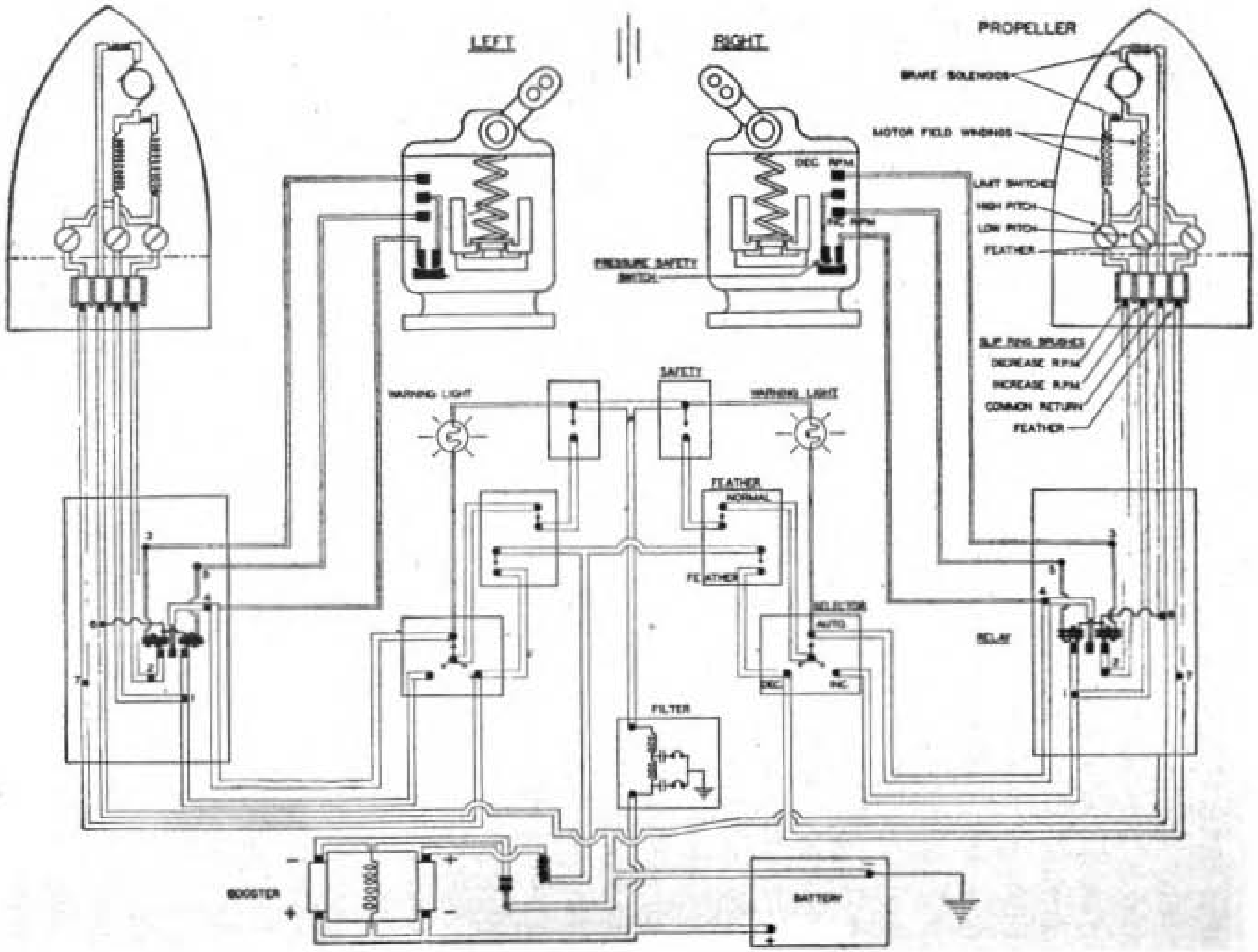
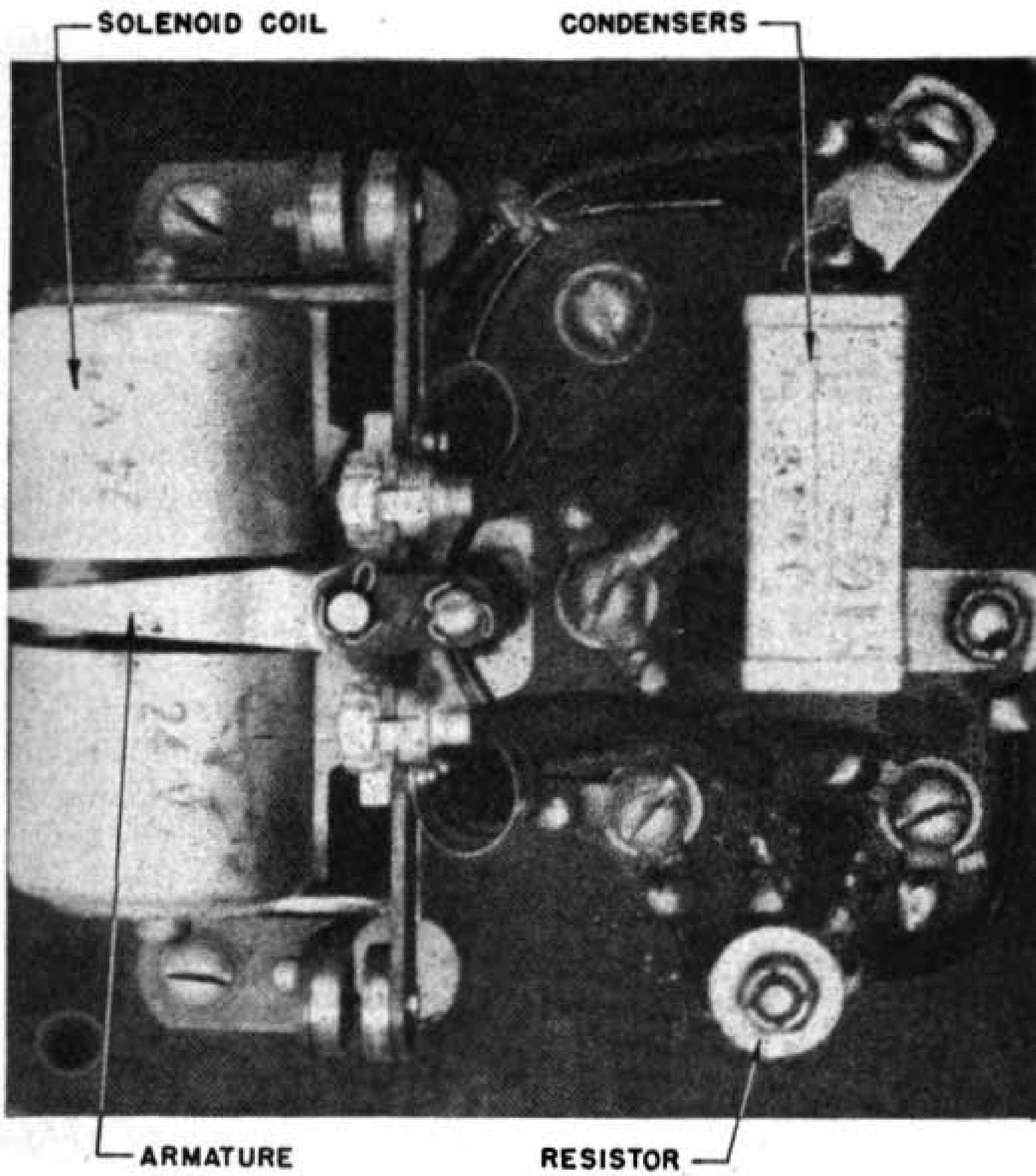
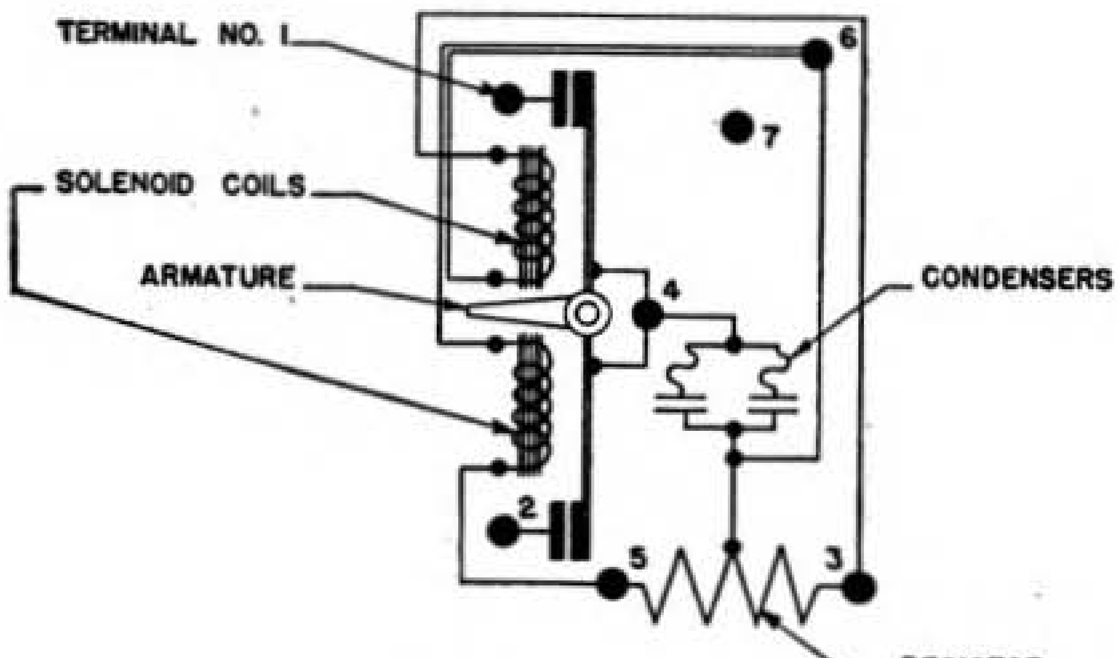


FIGURE 96.—Typical twin-engine wiring diagram.



① Relay.



② Wiring diagram.

FIGURE 97.—Relay, and relay wiring diagram.

rpm relay contact (fig. 96), depending on the change of engine rpm. The high current to operate the propeller pitch-changing mechanism is transmitted through the heavy relay points constructed to carry the high current. Because of the high resistance of the relay solenoid coils, the governor points carry only the small current necessary to energize the relay coils. In this manner, heavy current is kept out of the governor, which does not have contact points that could carry the heavy current for operating the pitch-changing mechanism.

(2) A resistor and a condenser assembly are also included in the relay circuit. The resistor dampens out small fluctuating currents and the condensers smooth out electrical pulsations which in some cases produce radio interference.

53. **Adjustment of controls.**—*a. General.*—The governor and the governor controls are properly adjusted when each setting of the governor control gives engine rpm corresponding exactly with the particular setting. That is, when the governor control is set at take-off rpm, the tachometer will show that the engine is actually operating at take-off rpm; when the control is set at cruising rpm, the engine will operate at cruising rpm and so forth. The throttle, mixture, and supercharger controls must also be in their proper positions, of course, to provide sufficient manifold pressure. In checking adjustment of the controls, it is important that at no time should engine rpm or manifold pressure exceed their rated values.

b. Adjustment of maximum-rpm stop.—The maximum-rpm stop of the governor is adjusted to give the proper maximum rpm for the particular engine and propeller. It is only necessary to connect the governor cockpit control properly to the pulley or control arm of the governor. (See installation procedure par. 56*c*.) However, if the maximum-rpm stop should get out of adjustment, necessary corrections will have to be made. To adjust or readjust the maximum-rpm stop, the following procedure will be followed except where limitations are listed on the ground run-up of specific engines:

(1) For trial setting, place the governor cockpit lever in the extreme rear position and the selector switch in AUTOMATIC.

(2) Turn the control arm attached to the governor control shaft in a clockwise direction to the minimum-rpm position or allow it to assume this position. When the control arm is in this position, the governor speeder-spring is compressed as little as possible.

(3) Connect the control cable or rod extending from the cockpit lever to the control arm attached to the governor control shaft.

(4) Loosen the increase-rpm stop screw and shift it away from the governor housing.

(5) Start and warm up the engine.

(6) With the engine warmed up, move the cockpit lever slowly forward until the engine tachometer reads the desired take-off rpm. Make sure that sufficient power is applied to insure automatic operation.

(7) Stop the engine, taking care that the setting of the governor lever in the cockpit is not disturbed.

(8) Adjust the increase-rpm stop screw toward the governor housing until it bottoms against it.

(9) A flight test must be made to insure that the governor is adjusted properly. If during flight the rated rpm cannot be obtained or if excessive rpm is encountered, readjustment of the controls is necessary.

c. Changing rpm.—To change the rpm, the maximum-rpm stop screw is loosened and shifted away from the governor housing. Another trial flight will be made and the cockpit control lever will be adjusted until rated rpm is obtained, the control quadrant being marked at this position. After the airplane is landed and the engine stopped, the cockpit control lever will be adjusted to the marking on the quadrant, and the governor stop reset. The mechanical linkage between the governor and the cockpit lever will then be readjusted (see par. 56*e*). The proper maximum-rpm setting is very important to prevent engine overspeeding and to give adequate power for take-off.

d. Adjustment of propeller low-pitch stop.—Occasionally the propeller mechanical stop or low-limit switch may be set so high that the blades are mechanically prevented from going to a low enough pitch to obtain rated rpm. If a slight movement of the cockpit control lever from the maximum-rpm position in the decrease-rpm direction has no effect on the engine rpm, this is probably the case. Obviously no governor adjustment can correct this condition. The propeller mechanical stop, or low-limit switch, must be readjusted. To check low blade-angle setting, put controls in fixed pitch at the low blade angle and check the rpm obtained with the manifold pressure at the recommended take-off value. This rpm should be approximately 25 to 50 rpm higher than the maximum rpm.

e. Caution in movements of controls.—All movements of the throttle and propeller cockpit control should be performed slowly.

Before checking the governor control, instructions for the particular airplane, engine, and propeller should be consulted in Technical Orders. If the governor control is not working properly, the necessary adjustments of the maximum-rpm stop and the mechanical linkage must be made.

54. Preflight operation.—*a. Starting engine.*—Except in an emergency, the starting of engines installed in airplanes with Curtiss electric propellers will always be made with either a battery cart, auxiliary power plant, or energizer when such equipment is available on the field. Before starting, be sure that the propeller cockpit switches and governor controls are set as follows:

(1) Set the thermal circuit breaker to the ON position if it is a toggle type switch, and to the IN position if it is a push-button switch. This switch should be ON or IN at all times.

(2) Set the selector switch to AUTOMATIC.

(3) Set the propeller control to take-off rpm. After the switches and governor are correctly set, the engine may be started and warmed up.

b. Checking propeller controls—manual operation.—When the engine is suffciently warmed up, the propeller controls should be checked as follows:

(1) See that the circuit breaker is in the ON or IN position.

(2) Place the selector switch in the OFF (center) position.

(3) With the engine running at approximately 1,000 rpm, check the manual propeller operation. This check is made with the selector switch first in the decrease-rpm and then in the increase-rpm position, making sure that engine speed responds accordingly.

c. Checking propeller controls—automatic operation.—(1) See that the circuit breaker is in the ON or IN position.

(2) Place the selector switch at AUTOMATIC.

(3) Set the propeller control at take-off rpm.

(4) Open the throttle to obtain 2,000 rpm, but not exceeding 30 inches (Hg) manifold pressure.

(5) Pull the propeller control back until a 200-rpm (approximate) reduction in engine rpm is observed.

(6) Return the propeller control to take-off position, noting that 2,000 rpm is again attained.

(7) Close the throttle.

(8) Where a warning light is installed, ascertain that it is not glowing.

d. Use manual selective control.—The Curtiss electric propeller is normally operated in automatic constant-speed control during

take-off, landing, and for all conditions of flight. The manual selective control is used in flight only in the event of failure of the automatic control.

e. Ground-checking the propeller.—On airplanes equipped with electrically operated gun turrets, radios, and other equipment using energy from the airplane battery, the Curtiss electric propeller should not be ground-checked from the airplane battery. An external electrical supply source, such as a battery or auxiliary power plant, should be used to make these checks. When this equipment is operated from the airplane battery, the result is a rapid discharge. Thus, when the engines are started, the electrical output of the battery to the propeller pitch-changing motor may be insufficient to permit this device to operate satisfactorily as a constant-speed propeller.

f. Ground-feathering the propeller.—Ground-feathering is not advisable, because of the excessive current required for the accomplishment of this change in propeller blade angle. If a check of the feathering operation is thought to be necessary, it should be from an external electrical supply source, if possible. In any case, the battery charge should be carefully watched, and it should at all times be sufficient to prevent overspeeding of the engine during take-off.

55. Feathering in flight.—*a. Emergency.*—In case of engine failure in flight, it is desirable to stop rotation of the engine. The propeller should then be feathered as follows:

(1) Throw the feathering switch to the feather position.

(2) Close the throttle.

(3) Move the mixture control to the idle cut-off position (depending on the type of engine and carburetor).

(4) Turn off the fuel supply.

(5) Leave the ignition switch on until the propeller stops, then turn the switch off.

b. Practice.—In practice feathering, the airplane must be above 5,000-feet altitude, and all engines must be operating satisfactorily.

(1) Close the throttle.

(2) Move the mixture control to the idle cut-off position.

(3) Turn off the gasoline supply to the engine.

(4) Throw the feathering switch to the feather position.

(5) Leave the ignition switch on until the propeller stops, then turn the switch off.

c. Unfeathering (return from feather position).—(1) Turn the ignition switch on with the throttle closed.

(2) Set the propeller control to the minimum-rpm position.

(3) Turn on the fuel supply.

(4) Move the mixture control to the full-rich position.

(5) Throw the feathering switch to the normal position, and hold the selector switch in the increase-rpm position until the tachometer reading reaches 800 rpm; then release the switch.

(6) Allow the engine to operate at 800 rpm until the required temperature is obtained. When unfeathering after the engine has cooled, it is important, before bringing the engine up to speed, to idle the engine at slow speed until it is thoroughly warmed up; otherwise serious damage may result. The windmilling action of a propeller is a very powerful cranking force and will easily over-speed the engine beyond safe idling speed unless care is taken to stop the blade-angle change at approximately 800 rpm.

(7) When the engine is sufficiently warmed up, throw the selector switch to AUTOMATIC and open the throttle, gradually causing the engine to speed up to the minimum rpm for which the governor is set.

(8) Adjust mixture, throttle, and propeller controls to the desired power and engine rpm settings.

56. **Removal and installation.**—The steps in removal and installation of the Curtiss electric propeller, three-blade (conventional) model, are as follows:

a. Removal.—(1) Before removing any propeller, first check to *see that the ignition switch is in the OFF position.*

(2) Operate the power unit until the minimum blade angle is obtained. (In some installations this must be done with the ignition on; be sure to return the ignition switch to the OFF position when the operation is completed.) This may be done by placing the selector switch in the increase-rpm position until the low-limit cut-out switch breaks the circuit. Check to see that the scribed line on each hub socket lines up with the proper low-angle setting on the degree scale on the blade shank (on the steel sleeve of aluminum-alloy blades).

(3) *Remove the brush cap from the brush housing on the nose of the engine.* This is important. Failure to remove the brush cap will result in damage to the brushes or the slip-ring insulators, or both, when the propeller is removed from the shaft. (It may be necessary to remove part of the engine cowling in order to remove the brush cap.)

(4) Remove the nose of the spinner and the power-unit cover or covers. Remove the bolts that hold the body of the spinner to the adapter plate.

(5) Remove the studs that hold the power unit to the hub, and remove the power unit. Support the power unit during this procedure; do not let it rest on the loosened studs. It is a good practice to remove the top two studs last, because the tendency of the power unit to shear these studs will be less than the tendency to shear bottom studs. Remove the power unit to a safe place.

(6) Remove the grease seal or seals from the propeller retaining nut.

(7) Unsafety the propeller retaining nut. To do this, remove the spring-loaded locking-pin assembly and the locking tube. (fig. 98).

(8) Loosen the retaining nut. This is done by inserting a bar through the bar hole in the end of the retaining nut. Loosen the retaining nut a few turns to draw the propeller partly from the shaft; then support the propeller by means of a hoist and hoist straps. When this is done, the retaining nut may be unscrewed the remainder of the way off the shaft.

(9) Screw thread protector on shaft, tightening by hand only. Remove the propeller from the shaft. Take care not to damage the shaft threads.

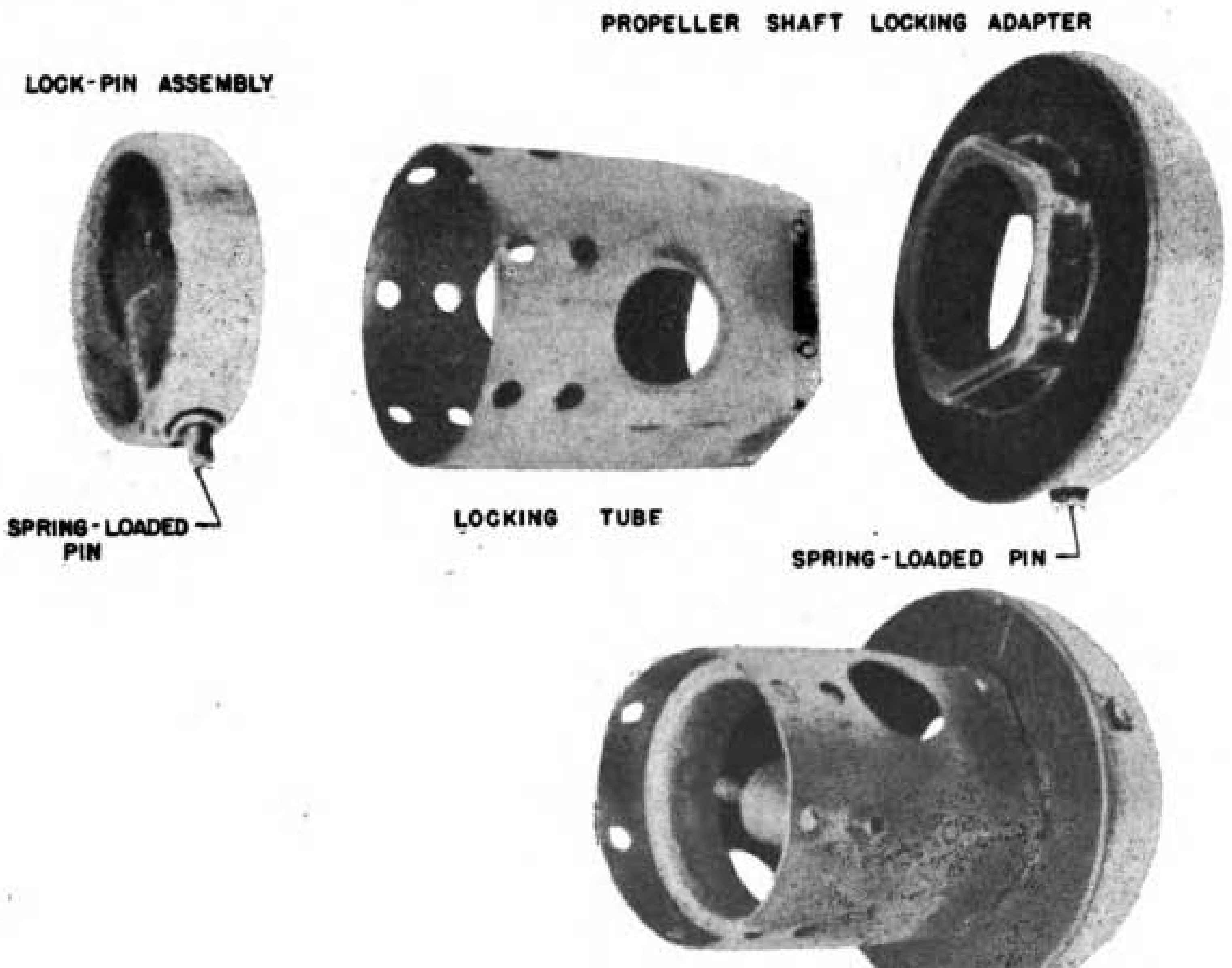


FIGURE 98.—Propeller retaining-nut locking device.

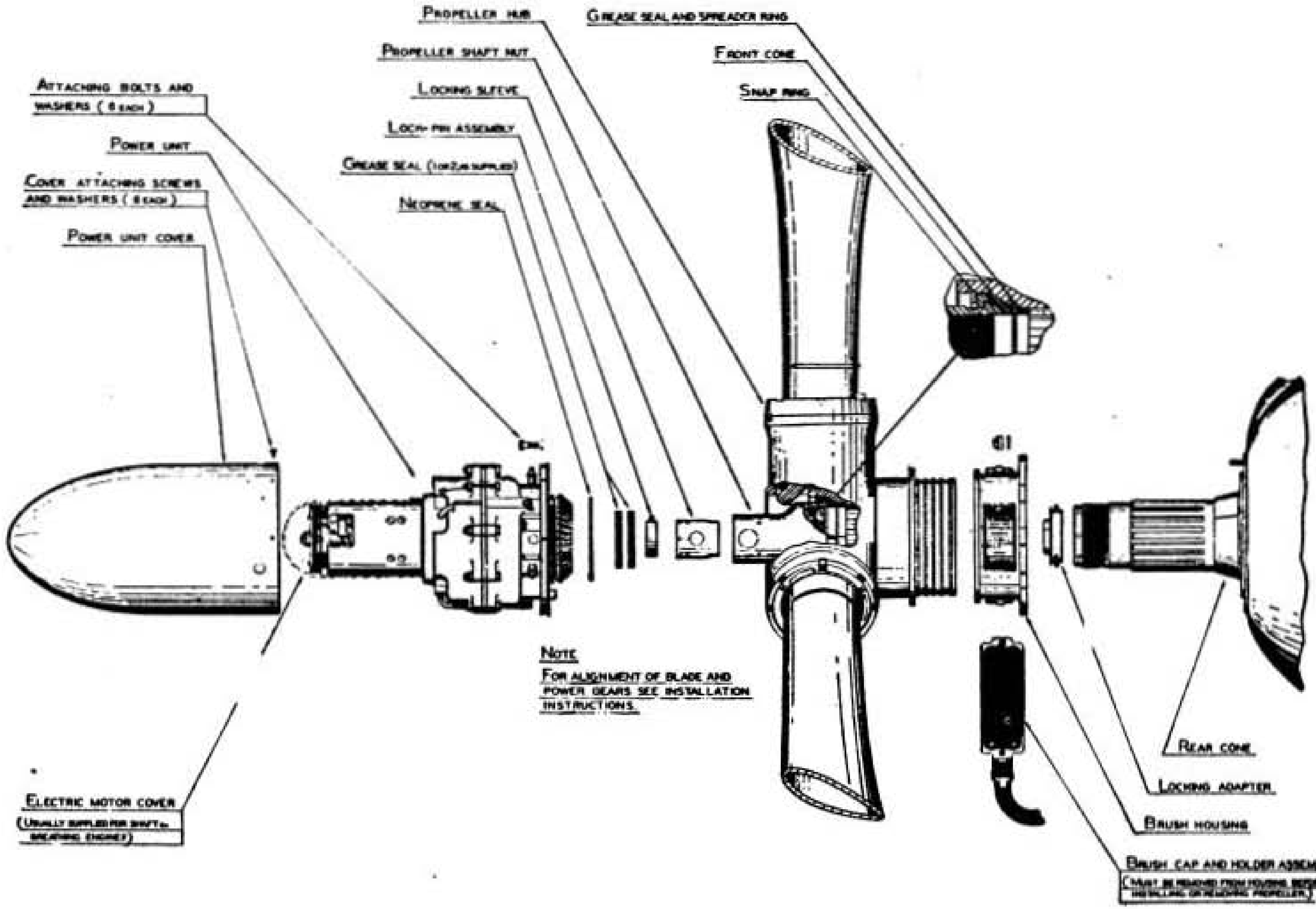


Figure 99.—Removal and installation chart, Curtiss electric propeller.

(10) Remove the thread protector; then remove the propeller-shaft locking adapter. If the shaft is to be exposed for any length of time, a propeller-shaft cap should be used to protect the shaft.

(11) Remove the bronze rear cone (fig. 99).

b. Installation.—(1) Before the propeller is installed, all component parts and controls should be examined for defects, damage, or improper fitting. Before installation, all corrosion and raised points of nicks, burrs, galls, scores, etc., on joining surfaces of the attaching parts, hub, and shaft should be carefully dressed off and the parts thoroughly cleaned.

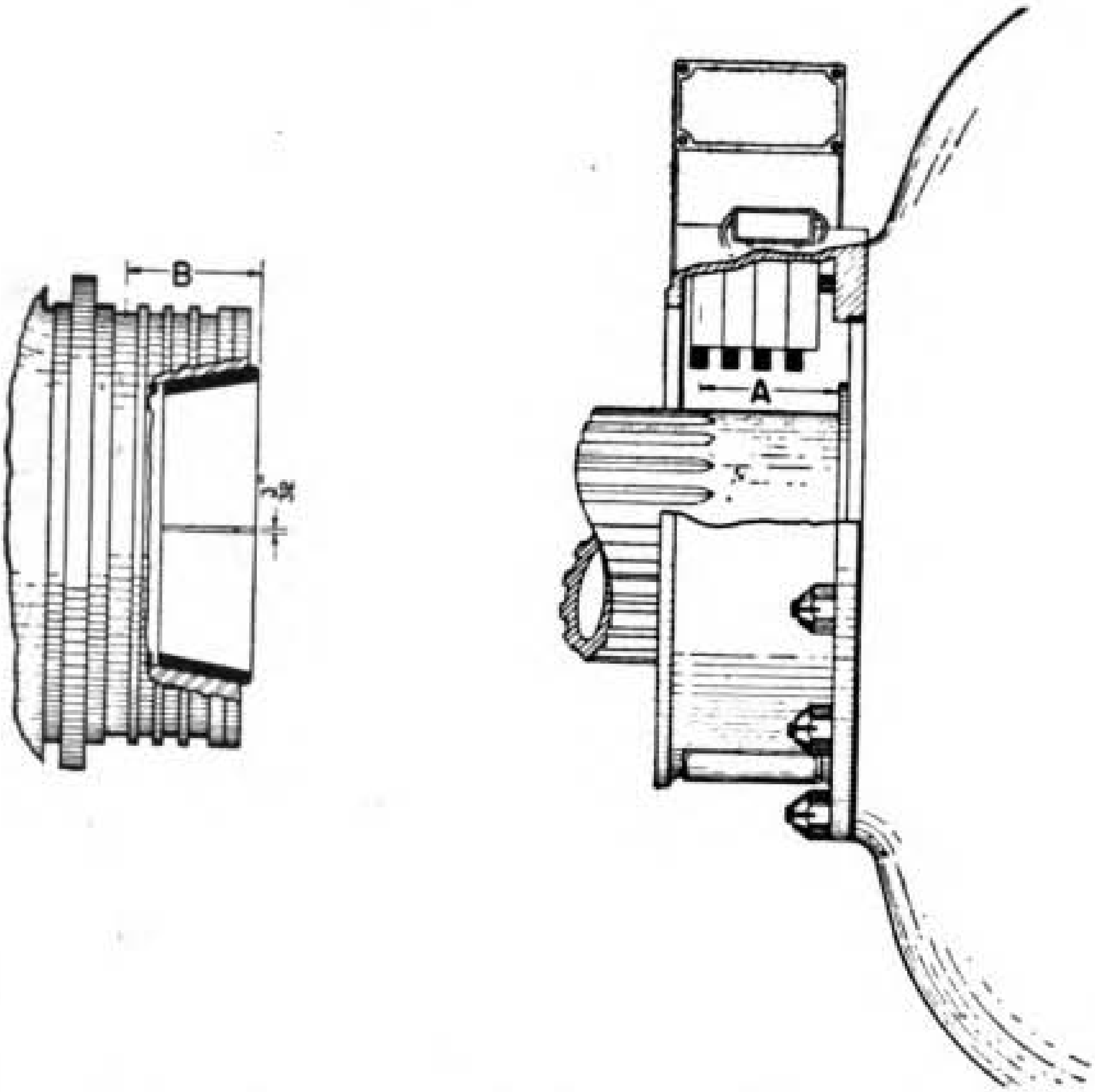


FIGURE 100.—Predetermining the location of brush contacts on slip rings.

(2) Determine the location of the brush contact on the slip rings. To do this before the propeller is installed, it is necessary to take the following measurements, as shown in figure 100. Measure the distance *A* between the face of the thrust nut and the center of the forward brush, and the distance *B* between the center of the front slip ring and the back of the rear cone, which should be held firmly against the cone seat in the hub. These two distances should be approximately equal, in which case the forward brush will ride in the center of the forward slip ring, and the other brushes will each ride in the center of its respective

slip ring also. If the difference between the two measurements is greater than 0.040 inch, shims should be added, as required, behind the rear cone or the brush housing. That is, if the distance *A* exceeds distance *B* by more than 0.040 inch, the brushes would ride too close to the forward insulators of their respective slip rings. To remedy this, shims of appropriate thickness should be placed behind the rear cone. The shims will move the whole propeller assembly, including the slip rings, forward, so that the brushes will ride farther from the forward insulators of the slip rings and nearer to the center of them. On the other hand, if the distance *B* exceeds distance *A* by more than 0.040 inch, the brushes will ride too close to the aft insulators of their respective rings. To remedy this, shims of appropriate thickness should be placed behind the brush housing. They will move the brush housing and brush cap forward, and the brushes will ride farther from the aft insulators and closer to the center of the slip rings. ***Caution:*** Except for the purpose of measuring for brush location as just described, the brush cap must be left out of the housing until the propeller has been installed. If the propeller were installed or removed with the brush cap in place in the brush holder, the brushes or slip-ring insulators, or both, would be damaged.

(3) Install the rear cone on the shaft.

(4) Place the propeller-shaft locking adapter in the end of the shaft.

(5) Apply a coating of an approved antiseize compound to the threads of the propeller shaft and propeller retaining nut.

(6) Coat the splines of the propeller shaft with a light coating of engine oil. The faces of the thrust nut, shims (if any), and the rear cone should be left dry.

(7) Screw thread protector on shaft. Tighten by hand only. Align the master or wide spline of the propeller shaft with the wide groove of the propeller and slide the propeller well back on the shaft. Care should be taken not to damage the shaft splines, threads, and the rear cone seat. Remove thread protector.

(8) Install the grease seal and spreader ring on the propeller shaft.

(9) Assemble the front cone over the retaining nut, and carefully start the nut on the shaft.

(10) Carefully tighten the nut on the shaft, at the same time pushing the propeller back on the shaft. For final tightening, a force of 250 to 300 pounds should be exerted on a 3½-foot bar placed through the bar holes in the nut. The bar must not be

jerked when this force is applied. Force should be applied steadily; hammering on the bar is unnecessary and should be avoided.

(11) Install the snap ring.

(12) A final check of the brush contact on the slip rings should be made. To do this, apply a light coating of prussian blue to the ends of the slip-ring brushes and place them in the housing. Rotate the propeller back and forth slightly and remove the cap. The brush track, as indicated by the prussian blue, should be in the approximate center of the slip rings and not closer than 0.020 inch to the slip-ring insulators. A feeler gauge should be used to check this clearance. If the brushes are riding too close to the slip-ring insulators either to the front or to the rear, shims as required to correct the condition will be added behind the rear cone or the brush housing. Since it will be necessary to remove the propeller and the brush housing to do this, a careful check before the propeller is installed may save much time and effort. When the brush contact on the slip rings is satisfactory, brushes and slip rings should be cleaned, and the brush cap installed.

(13) The safetying device of the retaining nut may now be installed. Fit the locking tube into the retaining nut until the five-sided end of the tube fits the raised nutlike portion of the propeller-shaft locking adapter. A lock-pin hole in the tube should line up with a hole in the retaining nut. If the holes are not aligned, it will be necessary to remove the tube and change its position on the adapter until the holes do line up. Place the lock-pin assembly in position; then release the spring-loaded lock pin, noting that it passes through both the locking sleeve and the propeller retaining nut.

(14) Install the grease seal or seals over the propeller retaining nut and check to see that the nut is satisfactorily tightened and locked.

(15) Clean the contacts on the face of the hub and the power unit, and place the neoprene grease seal on the adapter plate.

(16) Before installing the power unit, a check should be made to see that the low-limit switch arm is just riding on the low-limit lobe of the cam. To make this check, the power-gear assembly and adapter plate must be removed by removing the attaching screws and the snap ring at the end of the power-unit splined shaft. If the low-limit switch arm is not riding on its lobe, it is necessary to operate the power unit until it does. ***Caution:*** Before operating the power unit, the mechanical stop must be removed from the rear speed-reducer housing. This must be done to eliminate the possibility of damaging the aluminum housing by running into

the mechanical stop when the power unit is operated independently of the hub. The cam may then be rotated to the correct position by introducing a current through the proper two motor leads on the sides of the power unit beneath the beeswax seal.

(17) It is now necessary to index the power gear at the proper low angle. The power-unit drive gear has a master or index spline which is indicated by a mark on its end. The power gear is marked in divisions of 1°. To index the power gear, the proper degree marking on the power gear (the low blade-angle setting) should be lined up with the master spline of the drive gear. The power gear is then indexed in low pitch. Replace the three attaching screws in the adapter plate. Before the power unit is installed, the blade also must be indexed in low pitch. To do this, each blade must be rotated until the scribed line on the outside edge of the hub barrel lines up with the desired low-angle setting on the degree scale which is marked on the blade shank (on the steel sleeve of aluminum-alloy blades). Both the power gear and the blade gears are thus indexed in low pitch so that they will mesh correctly.

(18) Place the power unit on the hub, aligning the contact points and bolt holes of the power unit and hub. Push the power unit hard against the hub so that the power gear meshes with the blade gears. If it fails to mesh properly, check for proper indexing of the blades and the power gear. Secure the unit tightly to the hub with the six attaching bolts, and safety them.

(19) Lubricate the hub. (For detailed instructions see par. 57*h*.)

(20) Replace the mechanical-stop plug in the proper position as indicated by an "O" stamped on the stop and an "O" stamped on the housing. Inspect the index on the shank of the blades to see that they are properly indexed at the desired low-angle setting.

(21) Install the power-unit covers, engine cowling, and the spinner (if used).

c. Emergency installation of propellers.—Since fully assembled propellers require more space and are more difficult to pack and handle, factories and depots are shipping increasing numbers of propellers partially disassembled. In order that the propeller may be crated very compactly, all but one of the blade assemblies are usually removed from the hub. For this reason, the airplane mechanic must be thoroughly acquainted with the procedure of assembling blades in the hub. The steps are as follows:

(1) Remove the hub with its one blade from the packing case and carefully place the unit on any clean surface, with the slip

rings down. (Although a table or spindle is not necessary, such equipment will facilitate the work.)

(2) Thoroughly clean the blade sockets and coat them with clean, light engine oil.

(3) Place the gear backlash shims in the blade sockets, with the chamfered side toward the center of the hub.

(4) Carefully inspect the threads of the blade sockets and the blade nuts for wire edges, metal chips, and other imperfections, and make sure that the threads are absolutely clean. Thoroughly coat the threads with a white-lead mixture.

(5) Remove the locking plates which have been temporarily installed on the nuts of the removed blades.

(6) Insert one of the blades in its proper socket. The blade assembly number is stamped on each blade nut. The corresponding blade-socket number is stamped on the end of each socket.

(7) Screw the blade nut into the hub until one-half of the threads are engaged. While exerting an outward pull on the blade, tighten the blade nut with the spanner wrench provided and a 10-pound brass hammer (or its equivalent) until the paint marks on the nut and hub slots line up. If there are no paint marks, tighten the nut until it is barely possible to turn the blade by hand. However, a check should be made with a wooden blade beam to make sure the blade will rotate.

(8) After the proper slots on the blade nut and hub are aligned, install the locking plate and safety-wire the attaching screw.

(9) Repeat the foregoing procedure with the remaining blade.

(10) Each propeller is accurately balanced prior to shipment. When there is reasonable assurance that the propeller has not been changed in any way and that it has been properly assembled, the propeller may be installed on the propeller shaft without rebalancing. If there is any doubt as to the condition of any propeller, it should be rebalanced.

d. Removal of governors.—Removal of governors is accomplished as follows:

(1) Disconnect the control rod or cable from the governor control arm.

(2) Disconnect the conduit and wire connections by loosening the conduit nut and then unscrewing the electrical connector.

(3) Remove the lock wire and nuts which attach the governor to the engine drive-pad studs.

(4) Remove the governor and gasket. The engine drive-pad should be covered to prevent the entrance of dirt or other extraneous matter.

e. Installation of governors.—The governor is designed for mounting on the standard S.A.E.-governor drive pad on the engine nose, although special adapters are available to permit installation on the accessory drive on the rear of the engine. A gasket is furnished with the governor for installation between the governor and the engine pad. This gasket incorporates a screen and should be used on all governor installations. The standard gasket furnished with the engine should be discarded.

(1) Check to see whether the high-rpm stop is set at the proper rpm for the particular propeller and engine.

(2) Carefully mount the governor and gasket on the engine drive-pad studs.

(3) Screw the attaching nuts to the studs. Be sure that these nuts are tightened down evenly to prevent warping of the governor base. Safety the nuts with lock wire.

(4) Correctly align the electrical connector and screw it into place. Tighten the conduit nut into place.

(5) Place the propeller cockpit control approximately 1/8 inch from its most forward throw. Holding the take-off-rpm screw against its stop on the governor housing, attach the cockpit control to the control arm on the governor. A careful operations check should be made to determine that the governor control works properly.

57. Inspection and maintenance.—Inspection and maintenance are of prime importance to the proper functioning of the Curtiss propeller. Immediate discovery and correction of flaws and inaccuracies due to wear and operation are necessary. The following inspections and maintenance should be performed as specified in Technical Orders.

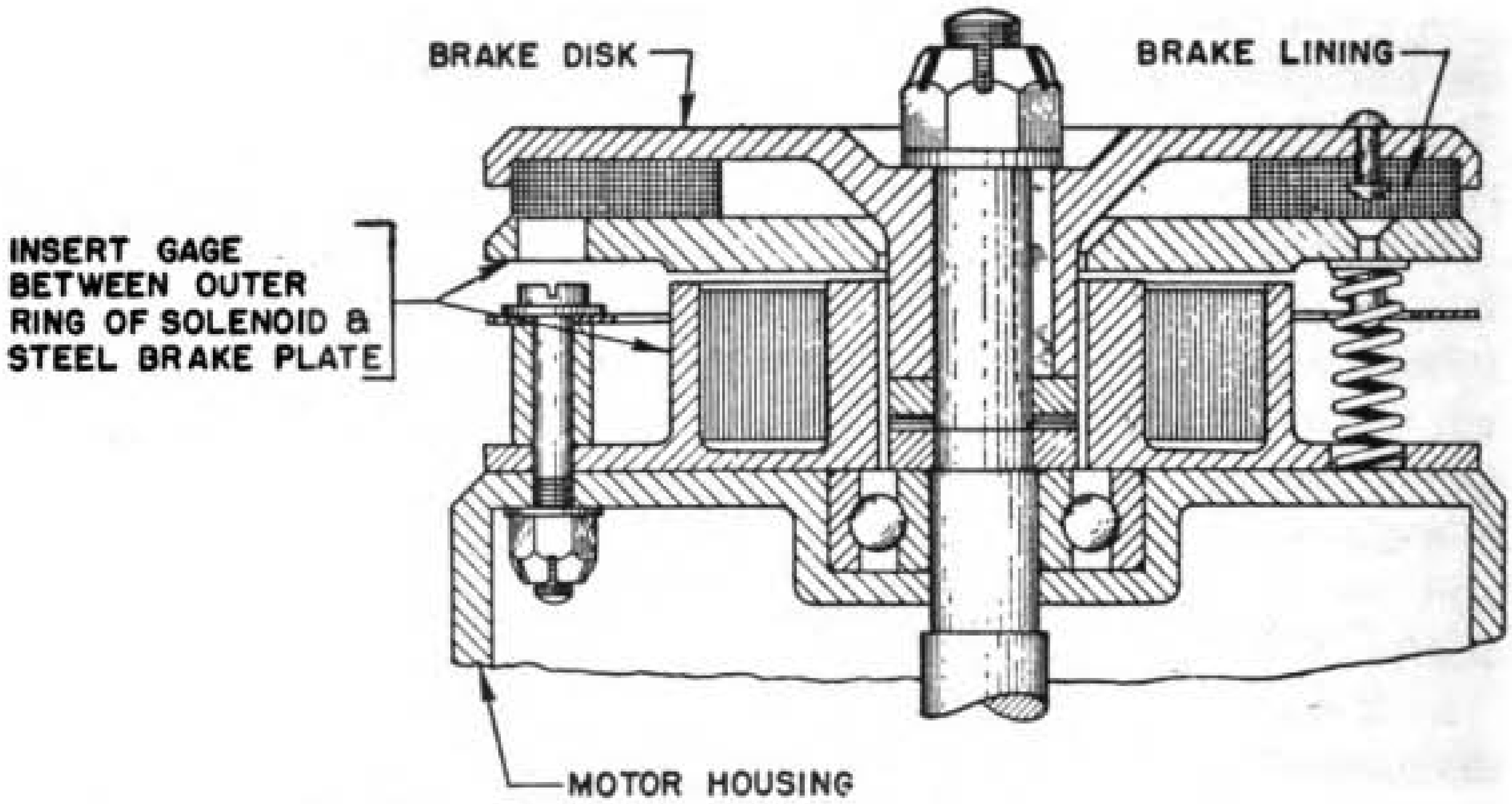
a. Brush holder and slip rings.—The brush assembly should be removed from the brush housing by unsafetying and releasing the two latches. Both the slip rings and the brushes should be inspected for wear. Clean the oil and carbon dust from the brush holder. If a cleaning fluid is used, care should be exercised that the fluid does not come into contact with the brushes. These brushes are impregnated with a lubricant which is soluble in most cleaning fluids. If this lubricant is removed, the brushes become dry, which will cause excessive wear of both the brushes and slip rings. Wipe the slip rings by holding a cloth against the rings while the propeller is being rotated by hand. Brushes used in some brush holders are scribed on the side with an arrow pointing toward the end of the brush. When the brushes are worn to the tip of the arrow or beyond, they must be replaced. If there are no

arrows on the brushes, determine whether or not they extend at least 3/8 inch from the block. If they do not extend this far, inspect for permanently compressed springs, and dirty guides before replacing brushes. The brushes must slide freely in the holder.

b. Checking retaining nut for looseness.—To check the retaining nut for looseness, first remove the cap from the brush housing. This is done to avoid damage to the slip rings in the event the retaining nut is loosened too far. The spinner nose, power-unit covers, and the power unit are then removed. The propeller retaining nut is unsafetied by removing the lock-pin assembly and the locking sleeve. A bar is inserted in the holes in the nut, and the nut loosened slightly and then tightened again with a force of 250 to 300 pounds on the end of a 3½-foot bar. The locking sleeve and the lock pin assembly are replaced to safety the retaining nut, and the power unit, power-unit cover, and spinner nose are replaced. The brush cap is then replaced in its housing.

c. Motor and magnetic brake.—To inspect the motor and the magnetic brake, remove the motor cover. Inspect the general condition of the electric motor (terminals and wire connections, tightness and condition of brush rigging). Check the brake clearance by using a feeler gauge between the brake plate and the outer ring of the solenoid housing (fig. 101). Refer to the latest Technical Order for the correct amount of brake clearance. If this clearance is too great or too small, it may be decreased or increased by removing or adding shim laminations on the armature shaft directly behind the shoulder of the brake disk. If the brake disk is removed, the brake facing should be checked. A glazed brake surface may be cleaned with a fine file. Badly worn facing should be replaced. When the inspection is completed, the motor cover should be replaced and safetied. On aluminum-alloy blade propellers having a floating brake plate, the brake clearance will be checked by inserting a thickness gauge between the floating brake plate and the inner ring of the solenoid housing. Refer to the latest Technical Order for the correct amount of brake clearance. To adjust clearance, do not remove nut on the armature shaft as the brake clearance cannot be adjusted from this point. Adjustment on this type of brake is accomplished by unscrewing the end-plate assembly and removing or adding the necessary number of laminated shims under the fixed friction plate to secure the desired clearance. After adjustment, make certain that the end-plate assembly is tight and safetied.

d. Checking propeller control switches.—At the regular inspection periods specified in Technical Orders, check the safety switch,



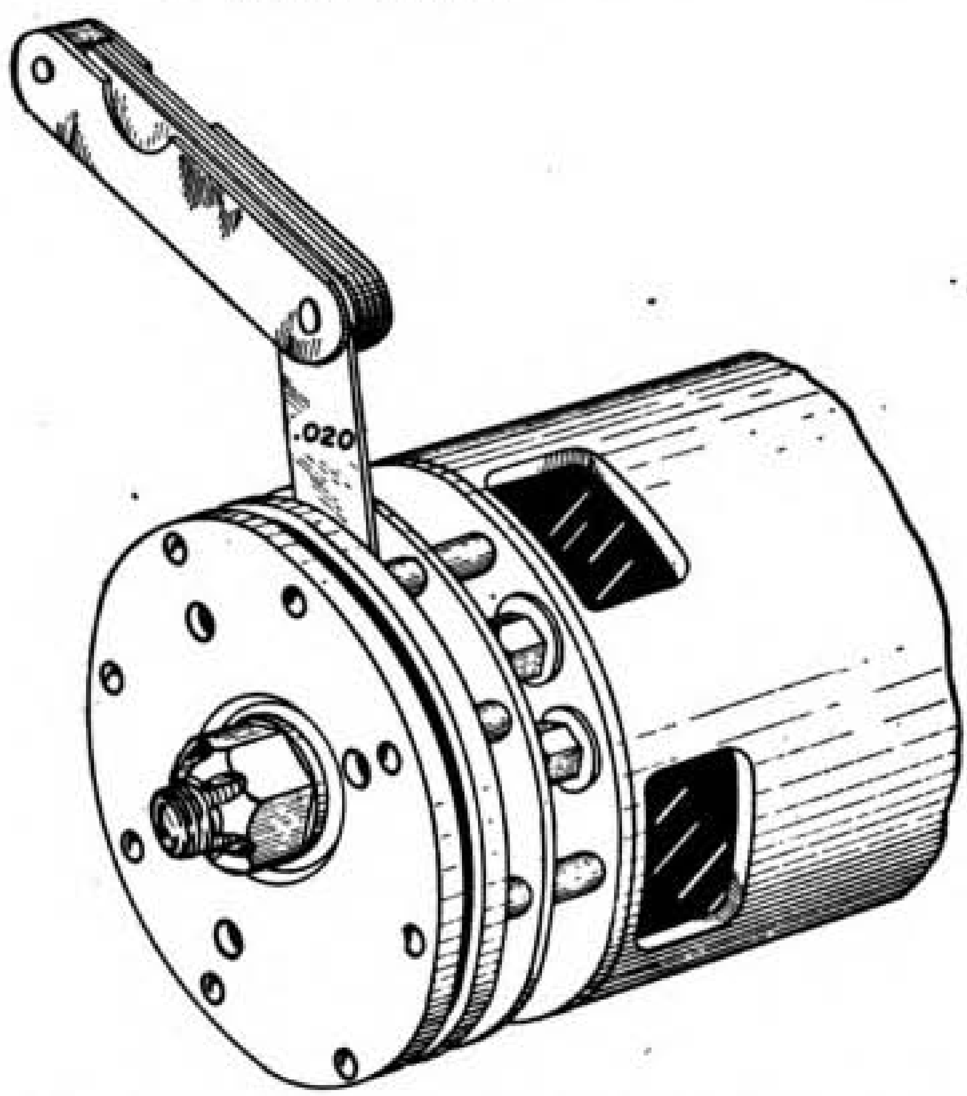


FIGURE 101.—Measuring the brake clearance, three-blade (conventional) model.

selector switch, and feathering switch. These switches should make positive contact and should be free from looseness or sluggish operation of the handles.

e. General propeller maintenance troubles.—Since the Curtiss propeller is operated electrically, many of the maintenance troubles are electrical. Frequent checks of the electrical equipment and wiring system for condition, cleanliness, and tight connections should be made.

(1) *Failure of pitch-changing motor to operate.*—If any one of the propeller circuits, completed by means of the selector switch or the feathering switch, does not operate the pitch-changing motor, that particular circuit is open. Make sure that the thermal safety switch is ON or IN, that the feathering switch is in the normal position (except when checking the feathering circuit), that the limit switches have not operated, and also that the battery is sufficiently charged.

(2) *Action of thermal safety switch.*—If the thermal safety switch kicks out when any of the propeller circuits are completed, there is probably a short in that circuit. Too small a clearance of the magnetic brake, causing an excessive current load on the system, might also cause the thermal safety switch to kick out. Insufficient brake clearance would also cause sluggish blade-angle change in both manual and automatic operation. If the blade angle changes beyond the desired setting, because the armature of the pitch-changing motor is "coasting" after the electrical circuit is broken, too great a brake clearance, or a glazed facing permitting the brake to slip when it is applied, is probably the trouble.

(3) *Failure of automatic control.*—If the propeller operates properly in manual control, but not in automatic control, that is, if any change of the governor control has no effect on the engine rpm, the trouble is obviously in the automatic propeller circuit. The trouble may be located in the relay, governor, or propeller controls.

f. Oil and grease leaks.—In connection with lubrication (see par. 57), the propeller must be checked for oil and grease leaks at the periodic inspections specified in Technical Orders. Several grease seals are necessary to prevent grease from leaking from the hub, and if grease is found leaking from the propeller, the most probable cause is a damaged grease seal.

(1) To prevent grease leakage from the hub, between the retaining nut and the power gear, then out the holes in the rear speed-reducer housing, one or two felt grease seals are placed over the propeller retaining nut before the power unit is installed.

Grease leaking from the holes thus indicates a defective propeller-retaining-nut felt grease seal.

(2) To prevent grease from leaking over the power-gear teeth and between the adapter plate to the front face of the hub, a neoprene grease seal is placed on a flange on the adapter plate. Grease leaking between the adapter plate and the front face of the hub indicates that this neoprene seal is defective.

(3) A spring-loaded neoprene grease seal is placed in the groove of the blade retaining nut to prevent grease from leaking from the blade socket along the shank of the blade. Grease on the shank of the blades probably indicates that this spring-loaded seal is damaged or that the blade retaining nut is loose.

(4) A neoprene seal and spreader are placed in a recess in the splines at the bottom of the front-cone seat. The apex of the front cone acts against the spreader to provide an oil between the hub and the shaft, so that grease from the hub will not leak back along the splines and out in the rear cone. Grease at this point indicates a defective grease seal in the recess.

(5) A seal fits between the steel sleeve and the shank of the aluminum-alloy blade. Grease on the blade shank near the sleeve indicates that this seal is probably defective.

(6) The speed reducer should also be checked for oil leaks. If oil is leaking from the speed-reducer housing, check the filler plug for tightness. If it is tight, one of the oil seals in this housing is probably defective, and the power-unit seals will have to be replaced.

g. Other propeller troubles.—Other maintenance troubles will occur which the mechanic will have to analyze and correct. An accurate and complete knowledge of the construction and operating principles of the propeller will enable him to determine these troubles quickly, and to correct them accurately. The mechanic must add to his knowledge by a close study of Technical Orders, and particularly by close attention to what he can learn from actual working experience.

h. Propeller lubrication.—The hub and the speed reducer are lubricated to insure efficient functioning of the moving parts of these assemblies. They must be properly lubricated at all times to prevent undue wear. The hub and power unit should be carefully checked for lubricant at the periodic inspection specified in Technical Orders.

(1) *Lubrication of hub.*—To check the hub for lubricant, rotate the propeller until the relief fitting on the speed-reducer housing just forward of the front hub face is at its highest point. Use a

pressure gun on the Zerk fittings, which are also located on the speed-reducer housing just forward of the front hub face. A solid flow of grease from the relief fitting will indicate that the hub is completely filled.

(2) *Lubrication of speed-reducer assembly.*—To check the speed reducer for lubricant, first remove the oil-filler plug, located near the front of the housing. If the airplane rests horizontally, rotate the propeller until the opening is approximately 8° below the horizontal. If the airplane rests at a ground angle of 12°, the plug opening should be approximately 20° below the horizontal when this check is being made. If the oil is just level with the plug opening, the speed reducer has the correct amount of lubricant. If the level of the oil is below the opening, the plug opening will be rotated to its highest point, and sufficient oil added.

i. Governors.—The following inspection and maintenance will be performed on the lubricated pad, proportional governor, and controls at the periods specified in Technical Orders:

(1) Visually inspect the condition of all flexible propeller conduits where possible damage may occur.

(2) Visually inspect the condition of control rods or cables in the engine nacelle.

(3) To inspect the proportional governor, remove the contact-switch cover. Inspect the condition, and see that the wire leads are securely attached. Thoroughly clean the contact assemblies with an approved cleaning solvent and remove any oil that may accumulate in the switch compartment. The contact points will not require dressing although their contracting surfaces should be cleaned with crocus cloth. Place not more than one drop of light lubricating oil on the upper end of the shaft which supports the center-contact assembly. Replace the cover. To inspect the lubricated-pad governor, remove the cover. Thoroughly clean the contact assemblies with cleaning solvent. Clean contact points with crocus cloth or fine sandpaper. Replace the cover.

(4) Examine electrical connectors, noting the condition of the sockets and pins. Coat the housing threads with antiseize compound. Make certain that the plug and receptacle are mated properly.

(5) Inspect the cockpit control lever to determine that it has at least ⅛-inch spring-back from the full forward position as an assurance that the governor control is fully against the stop, which is set for take-off rpm. Adjust control cables or rods if necessary, but do not adjust the stop screw on the governor, since it is already set to provide take-off rpm.

(6) Partially remove the relay from its box. Inspect for proper mating of contact points and sufficient contact-point pressure. The contact points of the relay do not require dressing or polishing; they are made of a hard material called elkonite. and the discoloration and fine pit marks which develop on the surface of these points are normal and do not affect conductivity. Next, make sure that the armature floats freely on its pivot pin. If necessary, lubricate it with a small quantity of oil. Then examine all terminals and wire connections, making sure that there is no possibility of the terminals touching each other. Finally, replace the relay in its box. Make certain that contacts are not fouled in any way.

SECTION IX

CURTISS ELECTRIC PROPELLER (HOLLOW-SHAFT MODEL)

58. **General.**—The Curtiss electric hollow-shaft propeller was designed to permit a cannon to be fired through the shaft. The hub and blade assemblies are similar to those of the three-blade (conventional) model. However, since it was necessary to build the power unit around the hollow shaft, the power unit of the hollow-shaft model is constructed quite differently from the one used with the three-blade (conventional) model. A number of major changes were necessary to prevent the power unit from interfering with the hollow shaft (fig. 102).

59. **Description.**—*a.* To understand the construction and operation of this propeller, it is necessary for the student to study the following paragraphs of section VIII:

(1) Paragraph 47, Models and model designation. This paragraph gives the model designation number of the hollow-shaft propeller, and explains its significance.

(2) Paragraph 48, Methods of pitch control. The working principles of this propeller are the same as those of the three-blade (conventional) model.

(3) Paragraph 49*a*, Hub. The hub of the hollow-shaft model is

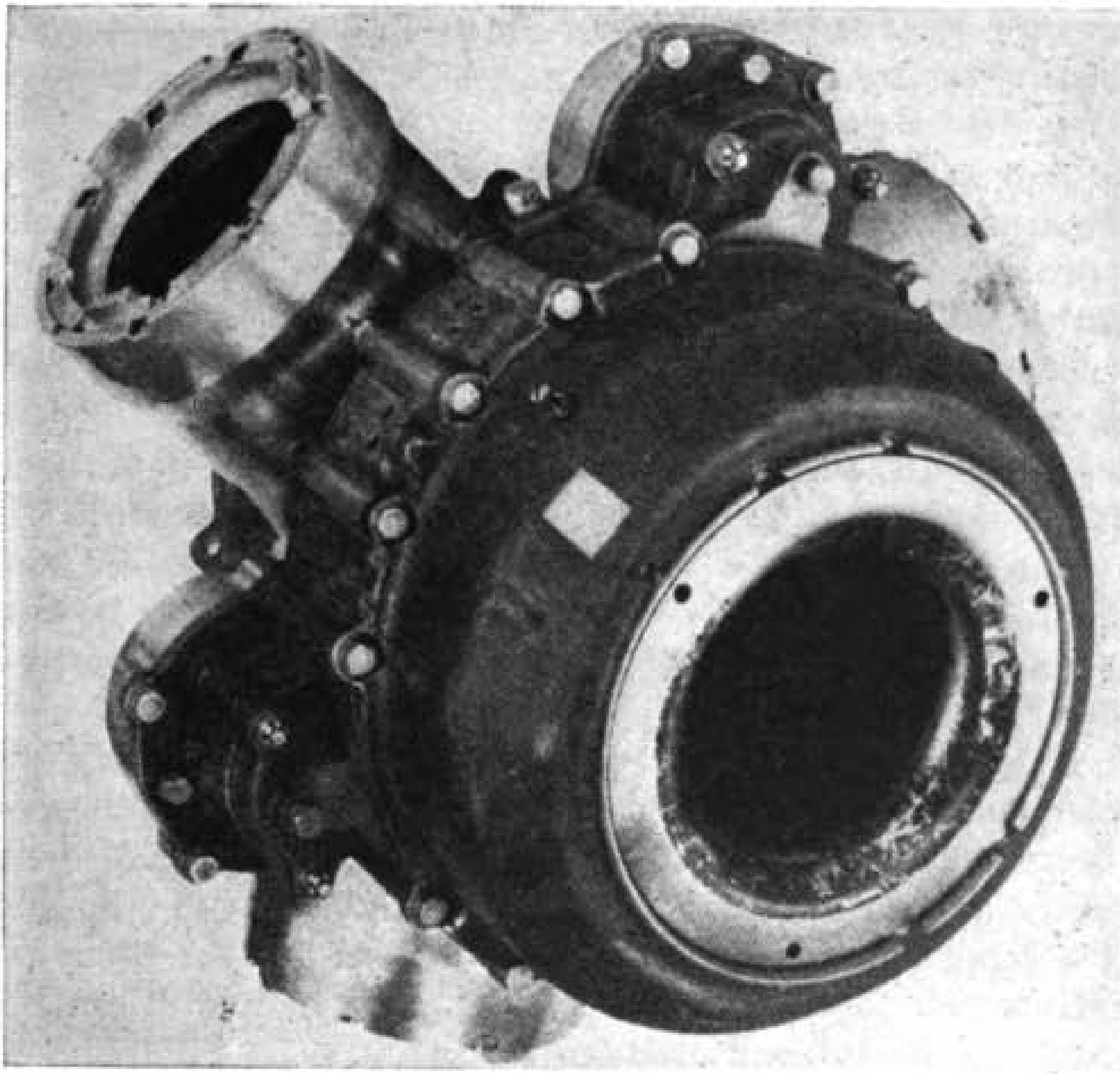


FIGURE 102.—Hollow-shaft-propeller hub and power-unit assemblies.

similar to that of the three-blade (conventional) model. The major difference is that the hollow-shaft-model hub has only three slip rings; this propeller does not have a feathering circuit. The brush block, therefore, has three rather than four rows of brushes.

(4) Paragraph 49*b* (1), Hollow steel blades, and 49*b* (2) Blade retention. The hollow-shaft model uses steel blades only.

(5) Paragraph 49*c*, Power unit. The working principles of the hollow-shaft-model power unit are the same as those of the power unit used with the three-blade (conventional) model.

b. Construction of hollow-shaft-model power unit.—Most of the parts of the hollow-shaft model power unit differ in great degree from the parts of the power unit used with the three-blade (conventional) model propeller. These differences are noted in the paragraphs that immediately follow:

(1) *Hollow armature.*—The armature of the pitch-changing motor of the hollow-shaft propeller is a large-diameter, sleeve type, or hollow, armature. The two field windings are arranged around the outside of it, and held in a suitable motor housing. The armature is equipped with a ball bearing and is mounted on the

inner motor housing. Built integrally with the inner side of the armature is the brake disk of the magnetic brake and a large spur gear that drives the gear assembly.

(2) *Gear assembly.*—The necessary reduction of speed between the armature and the power gear is accomplished in the hollow-shaft propeller by a three-stage gear-reduction train. The rotary motion of the armature is transmitted through this three-stage gear-reduction train to the power gear. The shaft is left hollow because small, individual speed reducers are fitted around it and are driven by the hollow-armature spur gear. They in turn drive the hollow spur-drive gear. The gear assembly is mounted in a front main housing and a rear housing, both of which are aluminum-alloy castings. The motor housing, gear-assembly housings, and planetary speed-reducer housings are bolted and screwed together to form the single compact power unit.

(3) *Magnetic brake.*—The magnetic brake of the hollow-shaft propeller operates in the same manner as the brake of the power unit described in paragraph 49*c*(6), but it is constructed quite differently. The brake disk, as has been stated, is built integrally with the inner side of the motor armature. All of the other parts are mounted on the main gear housing. This magnetic brake has has three solenoids connected in series with the pitch-changing motor armature, located between the individual speed reducer units. The brake plate is a steel ring that fits around the inner motor housing in front of the three solenoids and just behind the brake disk on the armature. Six coil springs are compressed between the brake plate and the main gear housing. Brake lining is attached to the face of the brake plate. This brake provides effective braking of the pitch-changing armature to prevent coasting and creeping, and it makes possible quick blade-angle changes.

60. Propeller and governor controls.—The lubricated-pad governor is used with the hollow-shaft propeller. This governor is described in paragraph 50. The propeller and governor controls and operation are similar to those described in paragraph 52. This propeller, however, does not have a feathering circuit.

61. Preflight operation.—The preflight operation of this propeller is generally the same as that given for the three-blade (conventional) model in paragraph 54. Specific instructions for the particular airplane and engine models should be consulted in Technical Orders.

62. Removal and installation.—The hollow-shaft propeller may be removed and installed with the power unit attached to the face of the hub. Therefore, some of the procedures in the removal and

installation of this propeller are different from those which must be followed during the removal and installation of the three-blade (conventional) model. The steps in the procedure for a hollow-shaft propeller are as follows:

a. Removal.—(1) Before removing any propeller, *first check to see that the ignition switch is in the OFF position.*

(2) Operate the power unit until the minimum blade angle is obtained. This may be done by placing the selector switch in the increase-rpm position until the low-limit cut-out switch breaks the circuit. Check to see that the scribed line on each hub socket lines up with the proper low-angle setting on the degree scale stamped on the blade shank.

(3) Remove the cap from the brush housing on the nose of the engine. This is important. Failure to remove the brush cap will result in damage to the brushes or the slip-ring insulators, or both, when the propeller is removed from the shaft. (It may be necessary to remove part of the engine cowling in order to remove the brush cap.)

(4) Remove the nose of the spinner.

(5) Remove the blast shield from the inner bore of the power unit.

(6) Remove the propeller retaining-nut locking assembly.

(7) Using the special wrench provided, loosen and remove the retaining nut from the shaft. (An additional spanner wrench is furnished for removing or tightening the propeller retaining nut while the gun is in place.)

(8) Remove the propeller from the shaft with the power unit attached to the face of the hub.

(9) Remove the bronze rear cone from the propeller shaft.

b. Installation.—(1) Before the propeller is installed, all parts should be examined for defects, damage, and improper fit. All corrosion, raised points, nicks, burs, galls, scores, etc., on joining surfaces of attaching parts, hub, and propeller shafts should be carefully dressed off and parts thoroughly cleaned.

(2) Determine the location of the brush contact on the slip rings (see par. 56*b* (2)).

(3) Install the rear cone on the shaft.

(4) Apply a coating of an approved antiseize compound to the threads of the propeller shaft and propeller retaining nut.

(5) Cover the splines of the propeller shaft with a light coating of engine oil. The faces of the thrust nut shims (if any), and the rear cone should be left dry.

(6) Align the master or wide groove of the propeller with the

wide spline of the propeller shaft and slide the propeller on the shaft until the retaining nut meets the end of the shaft. Care should be taken during this procedure not to damage the shaft splines, threads, or the rear-cone seat.

(7) Carefully tighten the nut on the shaft, at the same time pushing the propeller back. For final tightening, a force of 250 to 300 pounds should be exerted on a 3½-foot bar placed through the bar holes in the nut. The bar must not be jerked when this force is applied. Force should be applied steadily; hammering on the bar is unnecessary and should be avoided.

(8) A final check of the brush contact on the slip rings should be made (see par. 56*b*(12)).

(9) Safety the retaining nut. To do this, fit the locking assembly to the shaft nut so that the locking pin lines up with a hole in the nut and at the same time the assembly fits properly in the slotted end of the propeller shaft. If the hole does not line up, remove the locking assembly and change its position until a hole does line up. Be sure that the locking pin is properly seated in the propeller retaining nut.

(10) Install the blast shield and spinner.

c. Emergency installation.—The procedure for the emergency installation of this propeller is the same as given for the three-blade (conventional) model (see par. 56*c*).

63. **Inspection and maintenance.**—For inspection and maintenance of the brush holder and slip rings, the propeller control switches, the lubricated pad governor and the relay, see paragraph 57. The procedure for checking the retaining nut for looseness and the general maintenance troubles also apply to this propeller. The following inspection and maintenance applies to the hollow-shaft propeller only:

a. Motor and magnetic brake.—(1) To inspect the motor and magnetic brake of the hollow-shaft propeller, it is first necessary to remove the spinner nose and the blast shield. The outer motor housing must then be removed and the general condition of the electric motor determined. The distance that the motor brushes extend from the holder should be measured. If this distance is 3/16 inch or less, the brushes must be replaced. The brushes must slide freely in the holders.

(2) To check the brake clearance, a feeler gauge should be used between the brake facings and the armature. To make this check, the armature must be held securely against its locating shoulder with an armature clamp and the brake solenoids energized. (See fig. 103). The solenoids can be energized by introducing a current

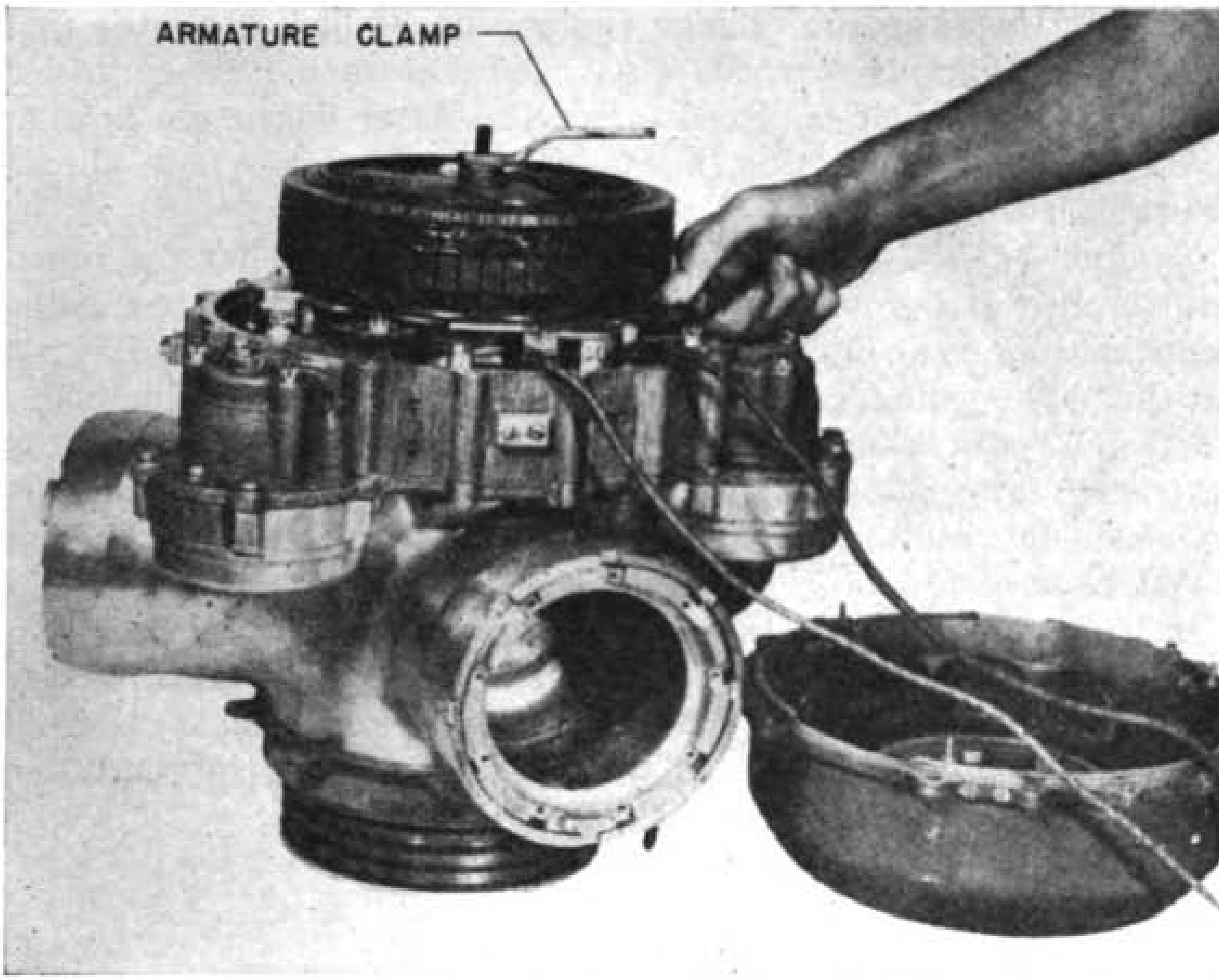


FIGURE 103.—Measuring the brake clearance, hollow-shaft propeller.

through the motor connector-socket terminal and the limit-switch terminal stud, both of which are located on the front main-gear housing between the No. 1 and No. 3 hub barrels. A satisfactory current for this check may be obtained by using 2 volts from one cell of a storage battery for a 12-volt propeller, or 4 volts from two cells of a storage battery for a 24-volt propeller. The brake should snap completely open with a current of not more than 35 amperes for a 12-volt propeller, and not more than 20 amperes for a 24-volt propeller. ***Caution:*** Never apply full battery voltage to the solenoids.

(3) With the solenoids energized, the brake clearance must be measured along the entire length of the three brake facings. Refer to the latest Technical Order for the correct amount of clearance. The clearance may be decreased on increased by adding or removing shim laminations between the base of the brake solenoid coils and the front-gear housing.

(4) With the armature clamp in place and with the brake applied, that is, with no current going through the solenoids, make sure that the brake facings seat against the brake disk. A clearance greater than that specified in the latest Technical Order at

any point between the facings and the brake disk indicates that the brake plate is warped. This condition should be corrected before the propeller is placed in service. After inspection is completed, the motor housing, blast shield, and spinner nose should be replaced.

b. Lubrication.—To check the hollow-shaft propeller for lubricant, rotate the propeller until the large filler plug, located in the rear housing, is at the highest point, and remove it. If the oil is not at the plug opening, completely fill the gear assembly to this point. Both the speed reducer and the hub are lubricated by this oil. It is extremely important that Technical Orders be consulted to determine the lubricant specified for this purpose. The correct lubricant must be used.

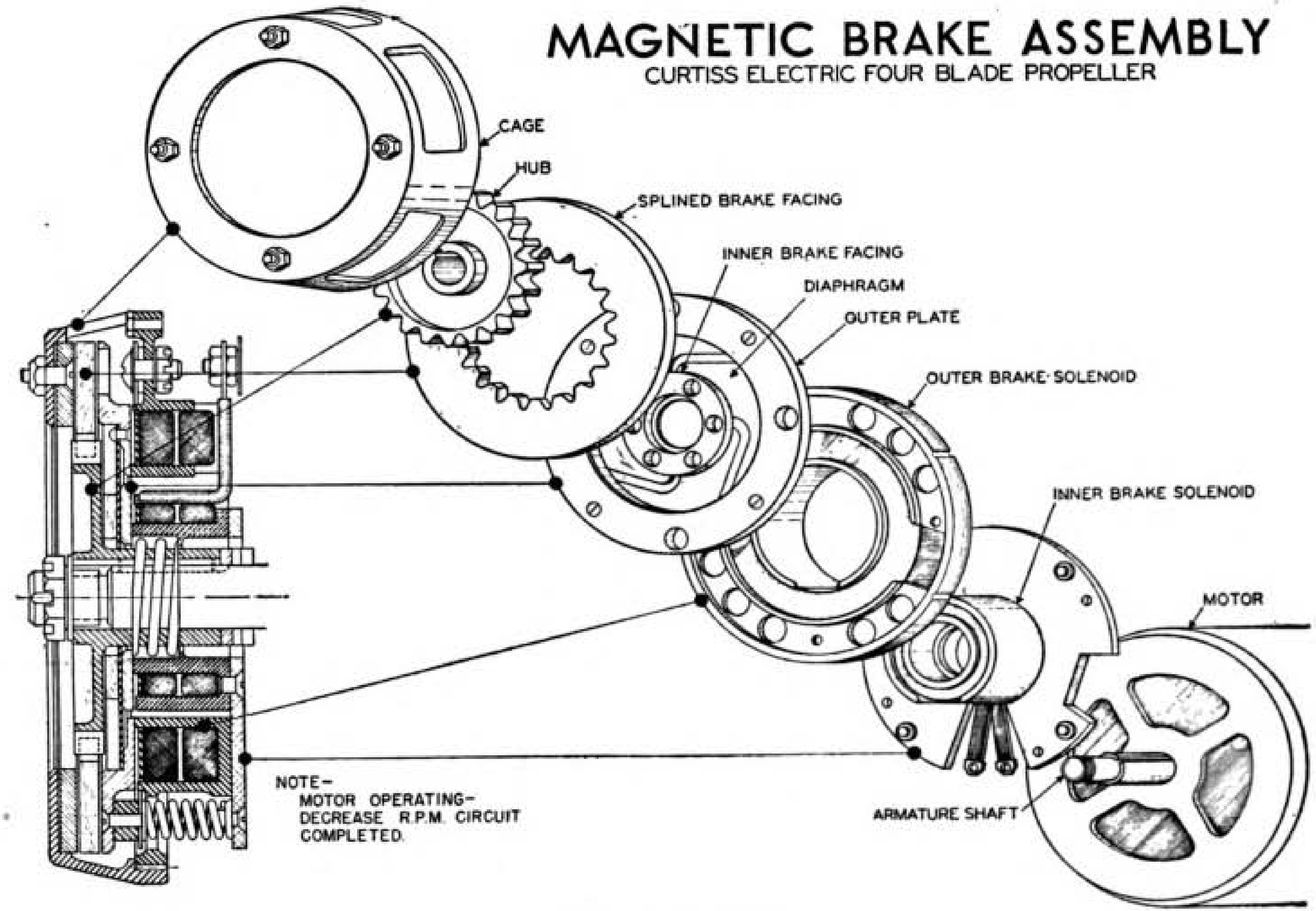
c. Oil leaks.—Should there be any indication that oil has been leaking from the propeller, it should be completely filled. If any considerable amount of oil has been lost, check the tightness of all nuts, bolts, and filler plugs. If this does not correct the condition, the propeller must be removed from the airplane.

SECTION X

CURTISS ELECTRIC PROPELLER (FOUR-BLADE MODEL)

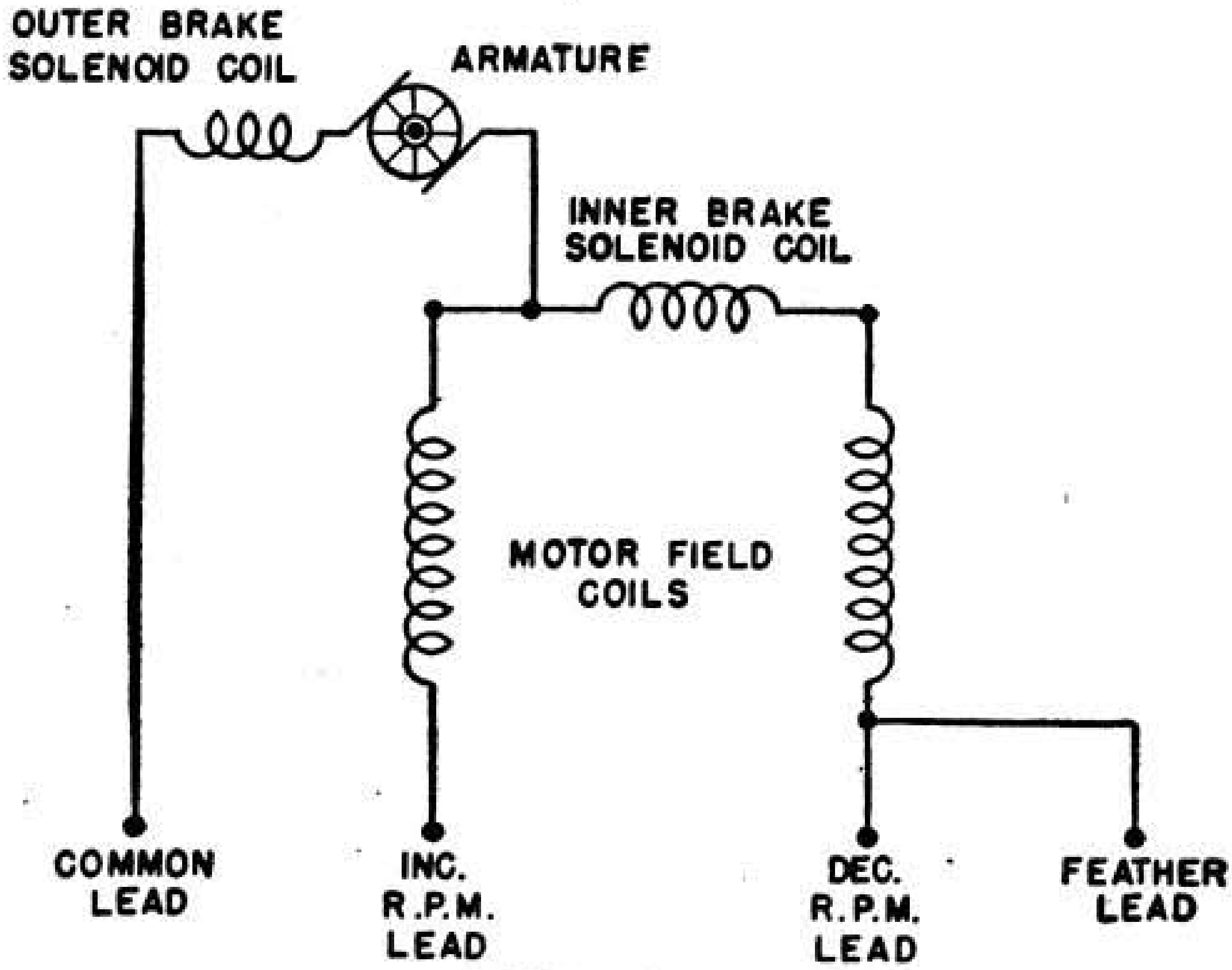
64. General.—The four-blade model of Curtiss electric propeller was designed to meet the need for propellers capable of absorbing the power of high-horsepower engines. Four blades provide greater attacking surface than three blades, and the power-absorbing ability of the propeller is thereby increased. In construction and principles of operation, the four-blade model is similar to the three-blade (conventional) model.

65. Description.—To understand the construction and principles of operation of this propeller, the student should study paragraphs 47, 48, and 49. The four-blade propeller uses steel blades only. The power unit of the four-blade propeller differs in a number of respects from the power unit of the three-blade propeller, and these differences are described in the paragraphs that follow:



① Brake assembly.

FIGURE 104.—Magnetic brake assembly, and power-unit wiring diagram of the Curtiss electric four-blade propeller.



② Wiring diagram.

FIGURE 104.—Magnetic brake assembly, and power-unit wiring diagram of the Curtiss electric four-blade propeller—Continued.

a. The chief differences between the three-blade-model power unit and the four-blade-model power unit are in the construction of the magnetic brake (fig. 104①).

(1) Because of centrifugal twisting moment, propeller blades tend to go to low pitch. The total twisting moment on four blades is greater than the total twisting moment on three blades, and for this reason the tendency of the four-blade propeller to go toward low pitch is greater than the like tendency of the three-blade propeller. The speed of the blade-angle change toward a lower angle, being aided by the low-pitch tendency, is considerably greater than the speed of the blade-angle change toward a higher angle, the latter being opposed by the low-pitch tendency, particularly on a four-blade propeller. It is desirable that the time required to decrease the blade angle be approximately equal to that required to increase it. The magnetic brake of the power unit of the four-blade propeller is designed to equalize these two speeds and at the same time to serve the same purposes as the magnetic brake of the three-blade propeller power unit.

(2) Two braking surfaces are used to equalize the speed of the blade-angle changes. When the blades are going toward a higher pitch, both surfaces are disengaged. When the blades are going toward a lower pitch, only one is disengaged. The engaged braking

surface serves as a drag to counteract the twisting moment, which tends to make the blades go to a lower angle too rapidly.

(3) These two braking surfaces are called the inner and outer brakes. A separate solenoid is employed for each braking surface. The inner solenoid is connected in series only with the decrease-rpm circuit of the pitch-changing motor. The outer solenoid is connected to the ground, or common return, and is energized whenever the pitch-changing motor is operating (fig. 104②). Therefore, when the decrease-rpm circuit is completed, both solenoids are energized because both are connected in the decrease-rpm circuit. In this case, the inner brake plate is drawn away from the rotating brake facing. The armature shaft is then free to rotate without braking force on it. When the decrease-rpm electrical circuit is broken, spring tension of coil springs reengages both the inner and the outer brake.

(4) If, on the other hand, the increase-rpm circuit is completed, only the outer solenoid is energized. The outer brake is released, but the braking surface of the inner brake plate is still engaged with the brake hub. The engaged inner plate is not sufficient to prevent the armature shaft from rotating, but it does cause sufficient drag to counteract the centrifugal twisting moment that tends to turn the blades to a lower angle. In one type of brake the outer brake plate has internal splines, and the inner brake plate is not splined; in another type, the outer brake plate is internally splined, and the inner brake plate is externally splined. In either case, the two plates may move back and forth independently of each other.

b. Mechanical stop.—Besides the differences in the construction of the magnetic brake of the power unit of the four-blade propeller, the mechanical stop is constructed somewhat differently. This power unit has a fixed mechanical stop built integrally with the adapter plate. This stop prevents the blades from going to positive low pitch in the event of a mechanical failure; but it is particularly designed as a safety feature to keep the blades within the flight range if the pitch-changing motor fails to stop at the low-pitch electrical stop. Since the mechanical stop is part of the adapter plate, the four-blade power unit, when removed from the propeller, may be operated safely only after the adapter plate has been removed.

66. Propeller and governor controls.—The proportional type governor is used with the four-blade propeller. This governor is described in paragraph 51. The propeller and governor controls and operation are the same as those described in paragraph 52.

67. Preflight operation.—The preflight operation of this propeller is generally the same as given for the three-blade (conventional) model in paragraph 54. Specific instructions for the particular airplane and engine models should be consulted in Technical Orders. Feathering instructions are the same as those given in paragraph 55.

68. Removal and installation.—The removal and installation, and emergency installation of the four-blade model are generally the same as these procedures for the three-blade (conventional) model. Minor differences are as follows:

a. During installation, it is sometimes necessary to operate the power unit until the low-limit switch arm is just riding on the low-limit lobe of the cam (see par. 56*b* (16)). On the four-blade propeller, since the fixed mechanical stop is built integrally with the adapter plate, the power unit may be safely operated to locate the cam only when the adapter plate has been removed.

b. The felt grease seal or seals are installed over the propeller retaining nut of the three-blade propeller, but are installed in the bottom of the power gear of the four-blade-model power unit.

69. Inspection and maintenance.—With the exception of checking the brake clearances, the inspection and maintenance of the four-blade propeller is the same as is given for the three-blade (conventional) model (see par. 57). The brake clearances of the magnetic brake assembly of the four-blade model unit are checked as follows:

a. To check the outer brake clearance, use a feeler gauge between the outer brake plate and the inner ring of the outer solenoid

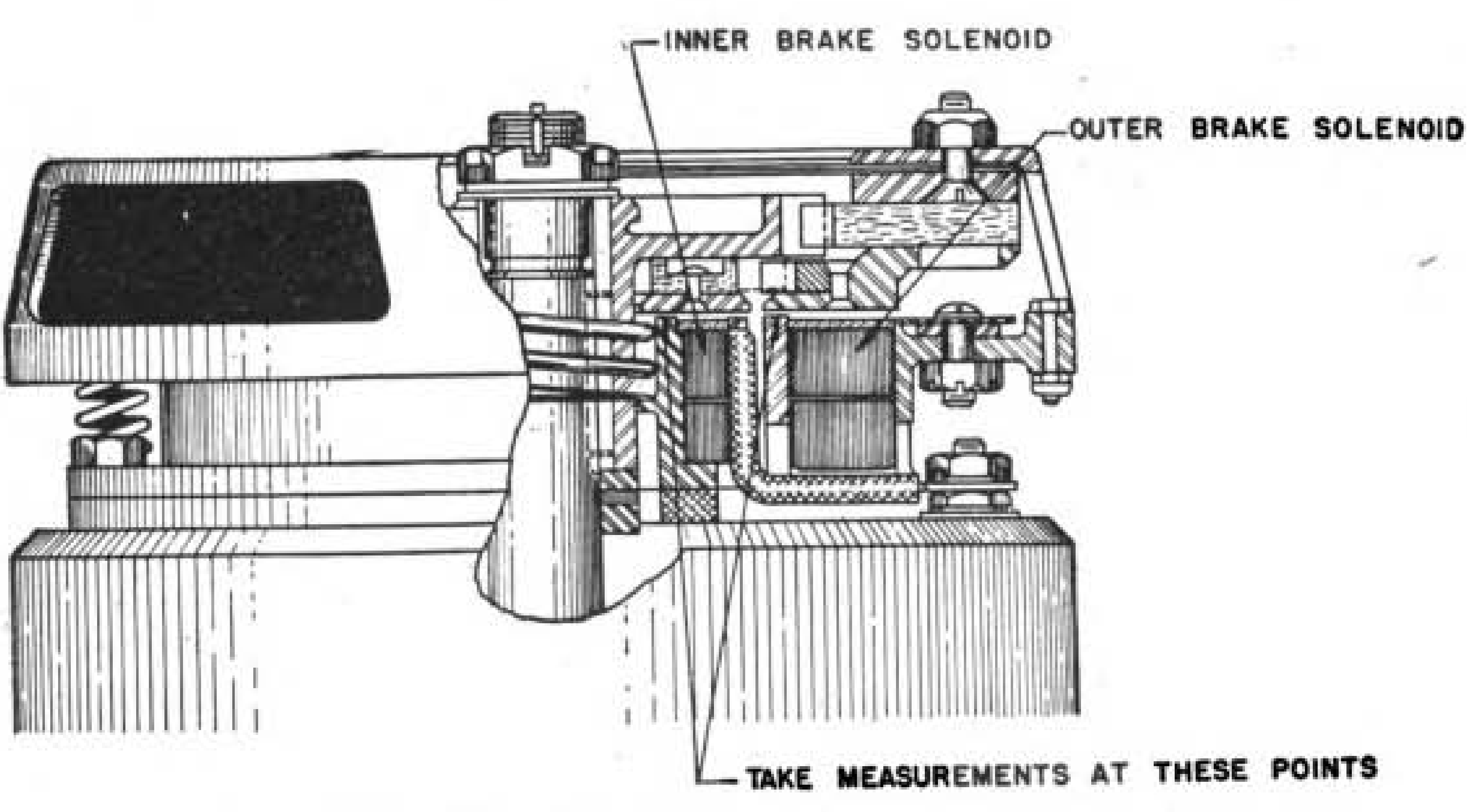


FIGURE 105.—Measuring the brake clearance, four-blade model.

housing (fig. 105). Refer to the latest Technical Order for the correct amount of clearance. The clearance may be decreased or increased by adding or removing shim laminations from the adjusting shim which is located between the forward brake plate and the brake cage.

b. To check the inner brake clearance, use a feeler gauge between the inner brake plate and the inner ring of the inner solenoid housing (fig. 105). Refer to the latest Technical Order for the correct amount of clearance. This clearance may be increased or decreased by adding or removing shim laminations on the armature shaft, directly behind the brake hub.

SECTION XI

GENERAL MAINTENANCE AND REPAIR

70. General.—*a. Importance of inspection and maintenance.*—Some inspections, maintenance procedures, and injuries requiring repair are common to all propellers. The mechanic should not underestimate their importance. These inspections and maintenance procedures are as necessary to satisfactory propeller operation as the repair and maintenance of any specific part in a particular propeller.

b. Repairs.—Bends, cuts, scars, nicks, scratches, and any other defects in blades or hub that may cause a crack to develop are serious injuries. These defects are the result of objects striking the blades and hub during flight and particularly during take-off and landing. If such a defect is left unrepaired, the local stresses that it sets up in the metal may cause a crack to develop, resulting

in the failure of the blade or hub. Propellers should be examined carefully for such injuries at periodic inspections, and any injuries found should be repaired immediately. Methods of inspecting for these injuries, determining their extent, and repairing them will be discussed in this section.

c. Other maintenance.—Other general maintenance includes: cleaning blades and hub for inspection; checking for track in the field; checking for deterioration of blade markings, antiglare, and camouflage; checking for and eliminating cone bottoming; and other inspections and repairs.

71. Cleaning for inspection.—All foreign substances must be removed from the surfaces to be inspected before a thorough and satisfactory inspection can be made.

a. Hubs.—Steel hubs are cleaned with soap and water, or with gasoline or kerosene, and suitable cloth or brushes. Tools and abrasives that will scratch or otherwise damage the plating should not be used.

b. Aluminum-alloy blades.—Warm water and soap, gasoline or kerosene, and suitable brushes or cloths that may be available and practicable are used for cleaning aluminum-alloy blades. Except in the case of etching and repair, scrapers, power buffers, steel wool, steel brushes, and any other tool or substance that will scratch the blade must not be used. In special cases where polish is desired on aluminum-alloy blades, a good grade of metal polish may be used, provided that on completion of the polishing all traces of polish are removed. This is necessary to prevent corrosion by acid contained in the metal polish.

c. Steel blades.—The foregoing instructions for cleaning aluminum-alloy blades apply also to cleaning the outside surfaces of steel blades, except that metal polish will not be used. If the necessary equipment is available, the inside surfaces of steel blades will be cleaned and recoated with rust-preventive compound in the following manner:

(1) Remove the old coating of rust-preventive compound with gasoline and kerosene and a long-handled swab.

(2) With a small electric lamp, thoroughly inspect for rust and other foreign substances, loosening of balancing solder and other defects.

(3) Remove all rust and other foreign substances that can be reached with suitable scrapers. Remove all obstructions from the vent hole in the blade tip.

(4) After the scraping is completed, thoroughly flush out the blade with gasoline or kerosene. Thoroughly dry the blade.

(5) Using the heavy rust-preventive compound heated to the proper temperature as specified in Technical Orders, immerse and thoroughly flush the blade at least three times.

(6) While the blade is hot, thoroughly drain the compound from all surfaces.

(7) With a clean cloth, remove the compound from all outside surfaces.

(8) See that the vent hole in the tip of the blade is not obstructed.

d. Removal of cleaner.—All cleaning substances must be removed immediately upon completion of the cleaning of any propeller part. Soap in any form will be removed by thoroughly rinsing with fresh water, after which all surfaces will be dried.

e. Coating with oil and rust preventive.—Immediately after the inspection and other work following each cleaning or etching, all unoiled surfaces of aluminum-alloy blades and steel blades of controllable propellers, and all hubs are coated with clean engine oil. Steel blades of noncontrollable propellers are coated with a rust-preventive compound as specified in Technical Orders. All outside surfaces are also coated with engine oil or a rust-preventive compound, as specified, upon completion of each day's flying. Exposed surfaces of blades and hubs installed, but not in actual service, are coated with clean engine oil or a rust-preventive compound, whichever is specified, as often as necessary to prevent corrosion. The coating of aluminum-alloy and steel blades of controllable propellers, and all hubs, with engine oil, and steel blades of noncontrollable propellers with a rust-preventive compound, serves two important purposes:

(1) The oil and the rust-preventive compound protect the exposed surfaces of the propeller from rust and corrosion.

(2) They also seep into cracks that might develop in the blade or hub, making the otherwise obscure cracks stand out.

f. Removal of salt deposits.—Propellers on airplanes operating near salt water must be treated carefully to prevent corrosion of blades and hub. As soon as possible after a flight near salt water, all traces of salt are removed by thoroughly flushing the propeller with fresh water. All parts are then dried and coated with clean engine oil or rust preventive compound, as specified.

g. Avoidance of caustics except in etching.—Except during etching, caustic material must not be used on any propeller. The removal of enamel, varnish, etc., from all propellers will be accomplished by the use of suitable solvents such as approved paint and varnish remover.

72. Inspection of aluminum-alloy blades.—*a. General.*—Aluminum-alloy blades are examined carefully for cracks or other failures, and for bends, nicks, scratches, and corrosion. The application of engine oil to the blades aids in this inspection, and a magnifying glass is also used. If there is any doubt as to the extent of certain types of injuries, local etching will be performed.

b. Local etching.—The purposes of local etching are—

(1) To determine whether visible lines and other marks within small areas of the blade surfaces are actually cracks rather than scratches.

(2) To determine, with a minimum removal of metal, when shallow cracks have been removed.

(3) To expose small cracks otherwise not apparent.

(4) To provide a simple means for accomplishing this work without removing or disassembling the propeller.

c. Etching solutions and containers.—(1) *Caustic soda.*—The caustic soda solution used in local etching is prepared locally by adding to the required quantity of water as much commercial caustic soda as the water will dissolve. To insure a saturated caustic solution at all times, a few soda pellets may be added after the water has ceased to dissolve the caustic. The quantity of the solution will depend on the amount of etching to be done. The caustic soda is used to reveal cracks, if any.

(2) *Acid.*—The acid solution is also prepared locally, one part commercial nitric acid being added to each five parts of water used. Handle the acid with care, and be sure to add the acid to the water (not water to acid) to avoid generating excessive heat. The purpose of the acid is to remove the dark corrosion that results when the caustic soda is applied to the metal.

(3) *Containers.*—Because they attack metal, the solutions are kept in glass or earthenware containers. If any quantity of either solution is accidentally spilled, it should be immediately flushed off the surface on which it was spilled (particularly if the surface is metal) with fresh water.

d. Procedures for local etching.—(1) The area of the aluminum-alloy blade containing the apparent defect should be thoroughly cleaned and dried. Masking tape may be placed around the suspected area to provide protection for adjoining areas.

(2) With No. 00 sandpaper, smooth off the area containing the apparent defect.

(3) With a small swab or stick, apply to the suspected area a small quantity of caustic solution.

(4) After the area is well darkened, thoroughly wipe it off with

a clean cloth dampened with clean water. (Too much water may remove the solution from a defect and thereby spoil the check.)

(5) If there is a crack or other defect extending into the metal, it will appear as a dark line or other mark. With the use of a magnifying glass, small bubbles may be seen forming in the dark line or mark.

(6) Removal of all defects is accomplished by means of fine sandpaper and fine-cut files (see par. 74). Several applications of the caustic solution may be necessary to determine if the shallow defect has been removed. Immediately upon completion of the final check all traces of caustic soda must be removed with the nitric acid solution, which in turn is thoroughly rinsed off with fresh, clean water. The blade is then dried and coated with clean engine oil.

73. Inspection of steel blades.—*a. Visual inspection.*—Covering steel blades with engine oil or rust-preventive compound, as required, aids in revealing otherwise obscure defects. The full length of the leading edge (especially near the tip), the full length of the trailing edge, the grooves and shoulders on the shank, and dents and scars should be checked carefully for cracks. Each apparent scratch must be examined carefully with a magnifying glass to determine whether it is a scratch or a crack.

b. Magnetic inspection.—A magnetic method of revealing small cracks in steel blades and steel propeller parts has been developed. The steel blade or part is mounted in a specially built machine. With a power supply of 2,000 to 3,000 amperes at 6 volts, the blade is magnetized by rapidly making and breaking the circuit through it two or three times. A black or red mixture of iron filings and kerosene is poured over the blade at the same time that it is energized. North and south magnetic poles will be set up on either side of any crack in the metal, and the iron filings will line up in the magnetic field thus created. A black or red line (depending upon which color mixture is used) will appear wherever there is a crack in the blade.

74. Repair of minor injuries to aluminum-alloy blades.—*a. Etching during repair.*—To avoid dressing off an excess amount of metal, checking by local etching will be done at intervals during the removal of defects and doubled-back edges of metal. Suitable sandpaper or fine-cut files are used for removing the necessary amount of metal, after which in each case the surface involved is smoothly finished with No. 00 sandpaper. Each blade from which any appreciable amount of metal has been removed is balanced before it is used. Cuts, scars, scratches, nicks, etc., can be removed

or otherwise treated provided their removal or treatment does not materially weaken the blade, reduce its weight, or impair its performance.

b. Narrow cuts, etc.—The metal around *longitudinal* surface cracks, narrow cuts, and shallow scratches is removed to form shallow saucer-shaped depressions, as shown in figure 106①. The limits to the repair of such injuries are as follows:

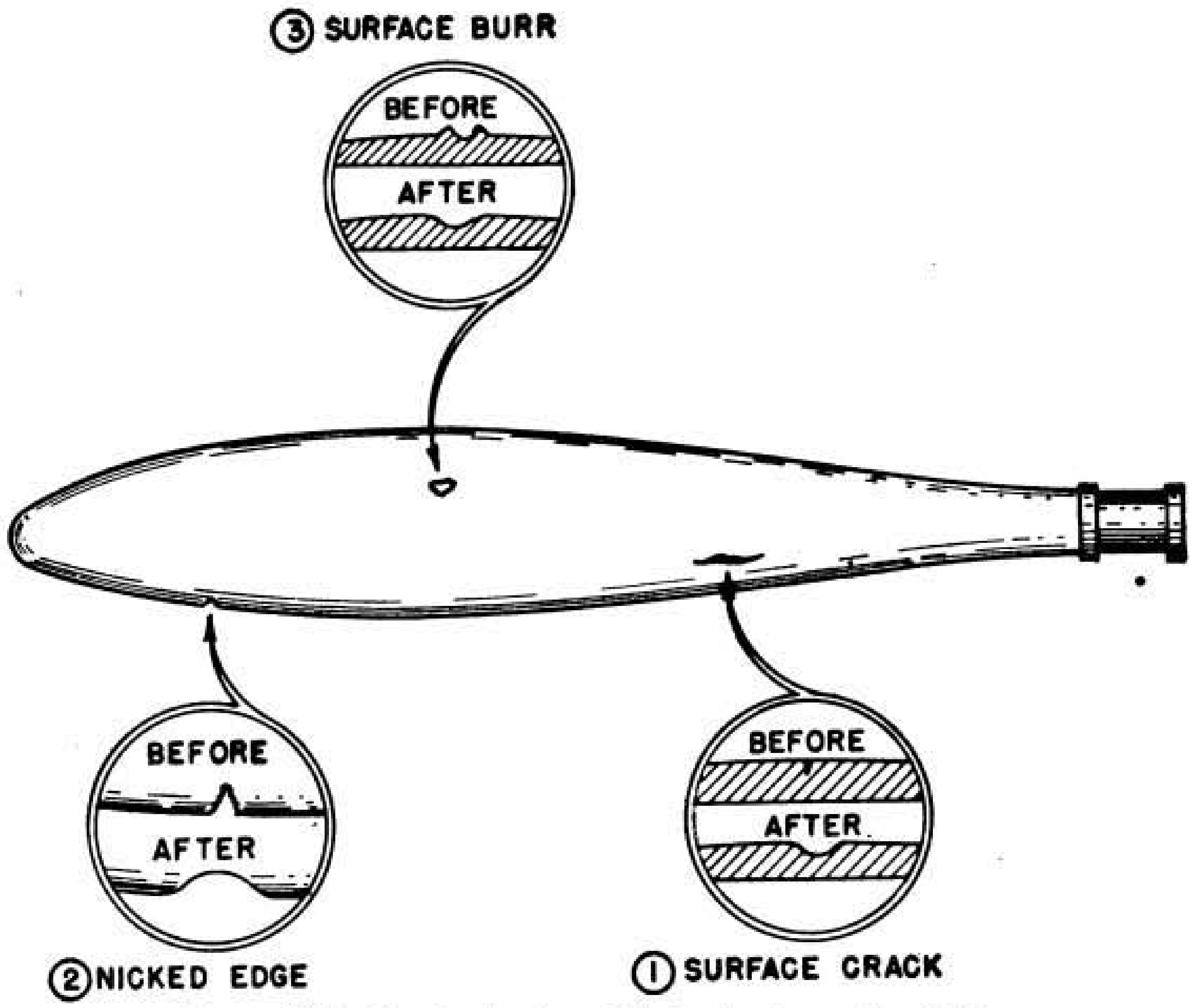


FIGURE 106.—Repair of minor defects, aluminum-alloy blades.

(1) Finished depressions formed by the removal of metal at the tip portion and extending 10 inches from the tip must not exceed $\frac{3}{32}$ inch in depth at the deepest point, $\frac{9}{32}$ inch in width over all, and $\frac{3}{4}$ inch in length.

(2) Finished depressions at areas other than the tip portion must not exceed $\frac{1}{8}$ inch in depth at the deepest point, $\frac{3}{8}$ inch in width over all, and 1 inch in length.

(3) Blades having finished depressions with dimensions exceeding those given in (1) and (2) above will be condemned.

c. Wider injuries.—Metal at the edges of wide scars, cuts, scratches, nicks, etc., on the leading or trailing edge is rounded

off and surfaces within the edges are smoothed out, as shown in figure 106②. The limits to the repair of such injuries are as follows:

(1) Removal of metal at the tip portion and in the area extending approximately 10 inches from the tip shall not exceed a depth of $\frac{3}{32}$ inch or a length of $\frac{9}{16}$ inch.

(2) Removal of metal at areas other than the tip portion shall not exceed a depth of $\frac{1}{8}$ inch or a length of $\frac{3}{4}$ inch.

(3) Removal of metal to a greater depth or length than the dimensions given will be cause for condemning the blade.

d. Raised edges.—Raised edges at wide scars, cuts, nicks, etc., on the blade surfaces will be carefully peened down to reduce the area of the defect and the amount of metal to be removed (fig. 106③).

e. Limit of "saucering out."—With the exception of cracks, it is not necessary to remove completely or "saucer out" all of a deep defect. Properly rounding off the edges and smoothing out the surface within the edges is sufficient, for it is essential that no metal be removed unnecessarily.

f. Multiple defects.—More than one defect, each falling within the limitations given, is not sufficient cause alone for rejection of the blade. A reasonable number of such defects per blade are not necessarily dangerous, if within the specified limits, unless their location with respect to each other is such as to form a continuous line of defects that would materially weaken the blade, or that would seriously affect the balance of the propeller.

g. Pitting.—Blades that have the leading edge pitted from normal wear in service may be reworked by removing sufficient material to eliminate the defects. In this case the metal is removed by starting approximately at the thickest section and working forward over the nose camber so that the contour of the reworked portion will remain substantially the same, without abrupt change in section and without blunt edges.

h. Condemnation.—An aluminum-alloy blade having any of the following defects will be condemned:

(1) A longitudinal crack, cut, scratch, scar, etc., that cannot be dressed off or rounded out without materially weakening or unbalancing the blade or materially impairing its performance.

(2) Unserviceability due to removal of too much stock by etching, dressing off of defects, etc.

(3) Bullet holes.

(4) A transverse crack of any size.

75. Repair of minor injuries to steel blades.—*a. Condemnation.*—In general, a steel blade having a crack, bend, or bullet hole

will be condemned. No attempt will be made to repair such a defect, except by specific authority.

b. Raised edges of injuries.—The raised edges of scars, cuts, scratches, etc., are dressed off by handstoning. The amount of metal removed should be as small as possible, so that there will be no abrupt change of section that would cause a stress concentration tending to induce a crack at any point. Under no circumstances should any other metal be removed, nor will other abrasives or tools be used for this purpose.

c. Dents.—Small, shallow dents located on the leading or trailing edge, or near the tip, are of no consequence, and therefore do not require repairs. Dents at other locations will be removed, provided that—

(1) The necessary tools are available.

(2) The strength and performance of the blade are in no way injured.

(3) The surface is restored to practically its original shape.

76. **Blade markings and coatings.**—*a. Markings.*—Between the 18- and 24-inch station on the cambered side, each detachable metal blade bears markings as follows:

(1) Army Air Forces serial number (all blades).

(2) Part number and/or model number (all blades).

(3) Blade-angle setting (all blades installed in a hub, whether in stock or on aircraft). This setting is the blade angle at the 42-inch station (unless another station is indicated) and is measured with the protractor. On all controllable propellers, the index setting (when applicable), maximum angle, and minimum angle are considered part of the blade-angle setting and should be marked on the blade.

b. Enamels and inks.—The foregoing data are painted or stenciled on an uncamouflaged aluminum-alloy or steel blade with black enamel, or are stamped with a rubber stamp and printer's ink. Yellow lacquer (same as that used on tip sections) is used on camouflaged blades. The size of the numbers and letters is ½ inch. In no instance will the markings be indented or cut into the metal. The markings will be protected by a coat of spar varnish or clear lacquer.

c. Decorations.—No decorative markings or coatings should be placed on blades or hub. Manufacturers' trade-marks are not considered decorative in this sense.

d. Antiglare.—To prevent glare, the face side of the propeller blades may be coated with antiglare. This coating extends from the 18-inch, or 24-inch station, as necessary, to the tip. Maroon

lacquer is preferred, but if not available, maroon enamel is used. After the coatings have dried, the propeller is checked for balance. Any unbalanced condition caused by application of finishes is eliminated by adding lacquer or enamel to the coated surface of the light blade. At no time will the antiglare be renewed or applied while the propeller is on an airplane.

e. Camouflage.—For camouflaging purposes, the propeller blades (except the yellow tips) and the propeller hub (unless covered by a spinner) are painted with a flat black lacquer. This is accomplished by spraying each propeller blade in a horizontal position and retaining the propeller in this position until the lacquer has set. When necessary the hub assembly is also sprayed. The propeller is then checked for balance. This finish on propeller blades and hub will chip and become unsightly after a period of use. It may be lightly "touched up" while installed on the airplane, but care should be taken to apply approximately equal amount of paint to each blade in order to maintain the proper balance. At overhaul, the assembly is repainted and balanced.

77. Front cones.—Hub front-cone halves are machined in pairs. The original mated halves will always be used together, and if one half becomes unserviceable, both halves will be disposed of. Serviceable front-cone halves will be securely taped together. The two halves of a front cone, before being used, are held together by a thin section of metal and must be sawed apart with a hacksaw. After the two halves have been separated, all resultant fine and rough edges are removed, and sharp edges where the cones are cut through are rounded off. This work is accomplished by careful handstoning.

78. Front-cone bottoming.—*a.* Because of manufacturing tolerances of certain propeller-shaft dimensions, a front cone occasionally "bottoms" against the outer ends of the propeller-shaft splines. In other words, the apex of the front cone strikes the ends of the splines before the cone properly seats in its cone seat in the hub. The retaining nut is tight, but the hub is loose because it is not properly seated and held tight by the cones.

b. Check for possible front-cone bottoming.—A check is made whenever a splined hub is installed. This check should also be made whenever the hub is loose, even though the retaining nut is tight, and there is no other apparent reason for this condition. If excessive propeller vibration during preflight operation cannot be traced to other causes, a check for front-cone bottoming should be made. The procedure follows:

(1) Apply a thin coating of prussian blue to the apex of the front cone.

(2) Install the propeller on the shaft and firmly tighten the propeller retaining nut.

(3) Remove the retaining nut and front cone and see if blue has been transferred to the ends of the splines of the propeller shaft.

(4) If no transfer is indicated the front cone is not bottoming. Clean off the prussian blue.

(5) If blue is transferred to the ends of the shaft splines, front-cone bottoming is indicated. This condition is corrected by installing a steel spacer behind the rear cone. These spacers are made locally and are 1/8 inch thick. Installation of the spacer moves the entire propeller assembly forward, and the front cone seats in the hub before its apex strikes the end of the shaft spline. A second check is made after installation of the 1/8-inch spacer, and if bottoming still occurs, a thorough check is made of the hub-shaft end, and all attaching parts for excessive wear or any other conditions likely to cause misfitting. Any worn or damaged parts will be replaced.

79. Preparation of propeller shafts for installation.—Before installing a propeller on a splined propeller shaft, the following maintenance should be accomplished:

a. Remove all grease, dirt, and other foreign matter with some approved cleaning fluid.

b. Inspect the threads of the shaft for corrosion, damage, and general condition, and clean thoroughly. Coat threads with thread lubricant as specified in Technical Orders for the particular propeller.

c. Inspect the splines of the shaft for corrosion, burs, raised points, and other damage, and remove defects with crocus cloth and by careful handstoning. Coat splines with clean engine oil. The use of cup grease is prohibited.

d. Inspect all attaching parts, such as front cones, rear cones, and spacers, and coat them lightly with engine oil, as required, before installing them on the shaft. However, the rear cone and its seat should always be installed dry. Determine if all parts bear the correct part numbers for the assembly.

80. Checking for track in the field.—*a. Preferred method.*—There are several methods of checking a propeller for track in the field; none of them, however, can be considered an accurate check. The preferred method is to attach one end of a rod to some part of the airplane so that the other end just touches the blade face near the extreme tip (fig. 107). Rotate the propeller until the next blade

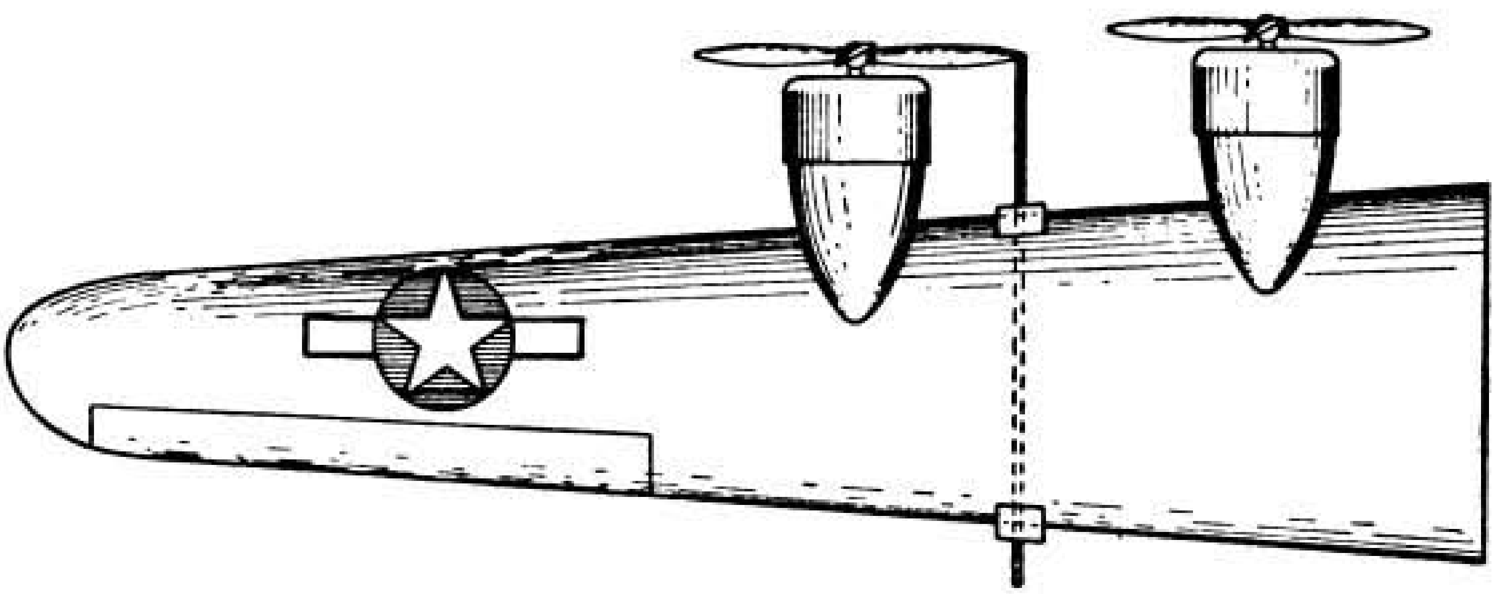


FIGURE 107.—Checking for track in the field.

is in the same position, and note the distance between the blade face and the end of the rod. Repeat the operation for each of the other blades. If attached to the landing gear, the rod should be attached above the movable part of the shock strut, as the turning over of the propeller may change the position of the strut relative to the airplane propeller. This method eliminates the necessity of blocking the wheels of the airplane, since any movement of the airplane will not change the position of the end of the rod relative to the blade face.

b. Out-of-track allowances.—(1) Allowances for out-of-track are as follows:

(*a*) Fixed-pitch wood propellers, $\frac{1}{16}$ inch.

(*b*) Ground-adjustable propellers with aluminum-alloy blades, $\frac{1}{16}$ inch.

(*c*) Ground-adjustable propellers with solid steel blades, $\frac{1}{16}$ inch.

(*d*) Ground-adjustable propellers with welded steel blades, $\frac{1}{16}$ inch.

(*e*) All controllable propellers, aluminum-alloy or steel blades, $\frac{1}{16}$ inch.

(2) Corrections are necessary if any two blades of a propeller are out of track in excess of these allowances.

81. Checking hub for looseness.—The following procedure is recommended for checking for looseness of the hub on the propeller shaft:

a. A stand or platform should be used to elevate the mechanic to correct working height. Grasp the hub with the hands, and attempt to move the propeller fore and aft on the shaft by pulling and pushing on the hub.

b. Any movement of the hub on the shaft is investigated and the

condition corrected before flight. Allowable motion in geared engine-reduction drives is considered when making this check.

82. **Checking blades for looseness.**—When checking the blades for looseness in the hub, the following procedure is recommended:

a. Turn the propeller until the blade to be checked is at the correct working height. Grasp the blade near the 42-inch station, placing one hand on the leading edge and the other on the trailing edge. Attempt to turn the blade in the hub.

b. Controllable propellers are usually assembled with some backlash in the blades; this should not be mistaken for looseness. If the blade is loose, or the backlash movement becomes excessive, the cause is determined and corrected before flight.

83. **Lubrication.**—To lubricate a propeller assembly with a grease gun, proceed as follows:

a. Procure the lubricant specified in Technical Orders for the particular propeller assembly.

b. Thoroughly clean the grease gun with gasoline or an approved cleaning fluid. If the grease gun is partly filled with lubricant of an unknown kind, it should be emptied and cleaned. If a hand type Zerk gun is used, inspect the condition of the plunger gaskets.

c. Fill the grease gun with the specified lubricant. If a power grease gun is used, adjust it to cut out at the specified pressure.

d. Test the gun and extension (if used) to determine if both are functioning properly.

e. Proceed with the lubrication according to instructions.

84. **Disposition of attaching parts.**—Common hub attaching parts (nuts, cones, snap ring, etc.) that are required when a controllable propeller is installed are obtained from stock. Special attaching parts which are not common to all types of propellers are furnished with each propeller. When a controllable propeller is removed, the attaching parts also are removed; the special parts remain with the propeller and all common parts are returned to stock.

85. **Special inspections.**—Special inspections are required in the following instances:

a. As soon as possible after a propeller strikes or is struck by an object, the propeller is carefully examined for possible damage.

b. On completion of each flight during which bullets pass through the path of propeller rotation, an examination for possible bullet damage is made.

c. A propeller involved in an accident is not used before it is first disassembled and the parts carefully inspected for damage and misalignment. All steel parts and otherwise serviceable steel blades

are checked for minor injuries by magnetic inspection. Aluminum-alloy blades, if otherwise serviceable, will be given a general etching by trained personnel.

d. If, for any reason, the propeller is removed from the shaft prior to the required overhaul inspection, the propeller-hub cone seats, cones, and other attaching parts will be inspected for galling, wear, bottoming, proper fit, etc. Before reinstallation, all defects will be corrected.

SECTION XII

UNIVERSAL PROPELLER PROTRACTOR

86. General.—To check blade angles accurately with the propeller installed on the airplane, a universal propeller protractor is used. This same device is also used to measure the throw of control surfaces. Graduations on the ends of the hub barrels or on the shanks of blades of propellers are used for routine inspections and emergency setting only; they do not provide an accurate check.

87. Description.—*a*. The propeller protractor consists of an aluminum frame in which are mounted a steel ring and a disk (fig. 108). On the disk is the main or "whole degree" scale; and on the ring is the vernier or "fractional degree" scale. The zeros on these two scales provide reference marks which can be set at the two sides of an angle, so that the reading from zero to zero will give the number of degrees of the angle. In order that the ring and disk may be properly adjusted, two adjusting knobs are provided. In the upper right-hand corner of the frame is the ring adjuster. When this knob is turned, the ring will rotate. The disk adjuster is located on the ring (fig. 108). Turning this knob will rotate the disk. Two locks are also provided on the protractor. One is the disk-to-ring lock, located on the ring. This lock is a pin that is held engaged by a spring. It engages only when the pin is pulled outward and placed in the deep slot, and when the zeros on the two scales are aligned as shown in figure 108. In this case, turning the ring adjuster will cause the ring and disk to rotate together (provided the ring-to-frame lock is disengaged). The spring-loaded pin of the disk-to-ring lock is pulled outward and turned 90° to hold it in the released position. The other lock is the ring-to-frame lock,

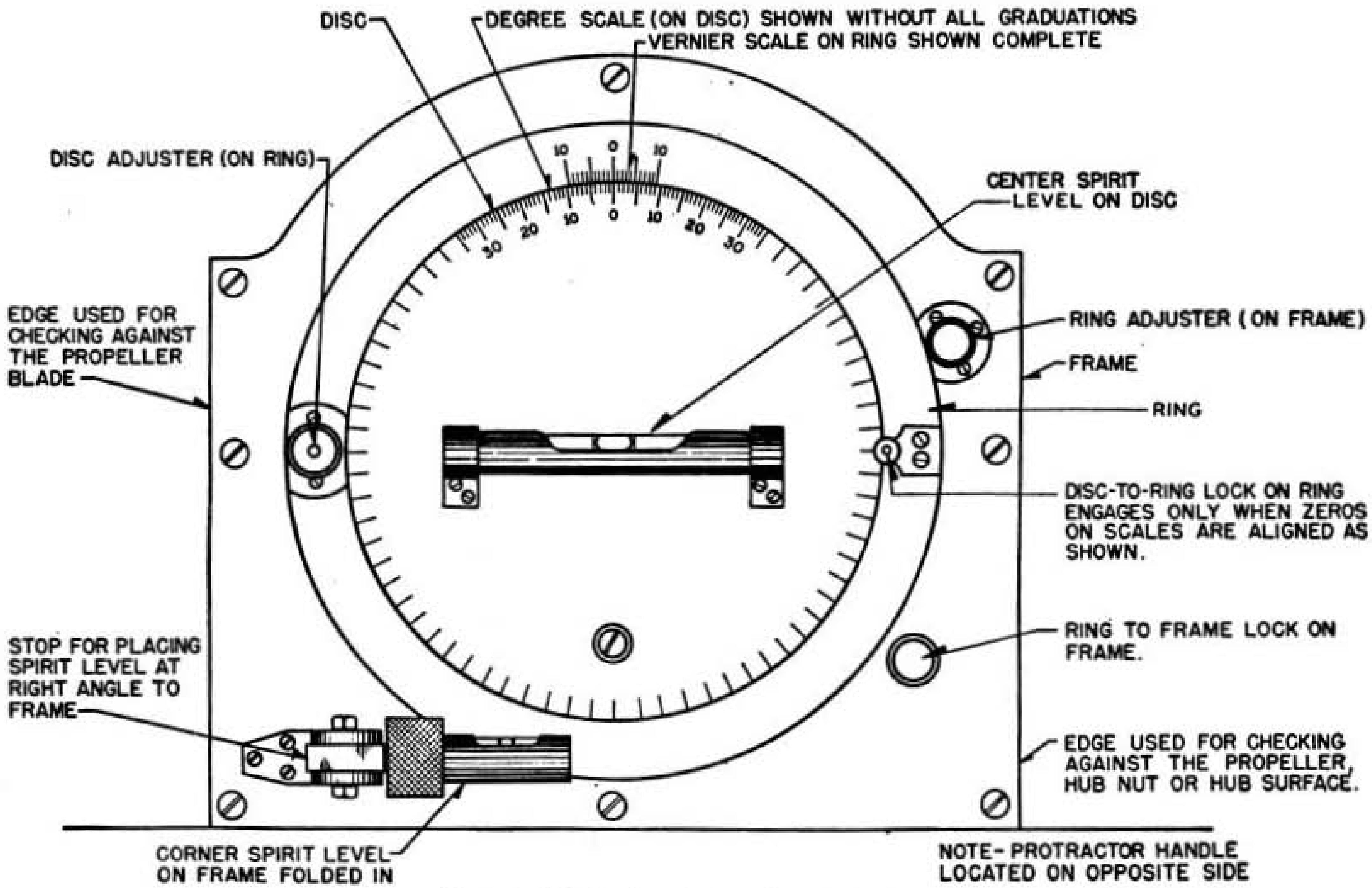


FIGURE 108.—Universal propeller protractor.

located on the frame. This lock is a right-hand screw with a thumb nut. When the ring is locked to the frame and the disk-to-ring lock is released, the disk may be turned independently of the ring by means of the disk adjuster.

b. The protractor has two spirit levels. The center or disk level is at right angles to the zero graduation mark on the whole-degree scale of the disk; therefore, whenever the disk is "leveled off" in a horizontal position by means of the disk level, the zero graduation mark will lie in a vertical plane through the center of the disk. The corner spirit level, located at the lower left-hand corner of the frame, is mounted on a hinge. When the protractor is to be used, this level is swung out at right angles to the frame. By means of this level the protractor can be kept in a vertical position, which is necessary for an accurate check of the blade angle. A handle on the back of the frame completes the universal protractor.

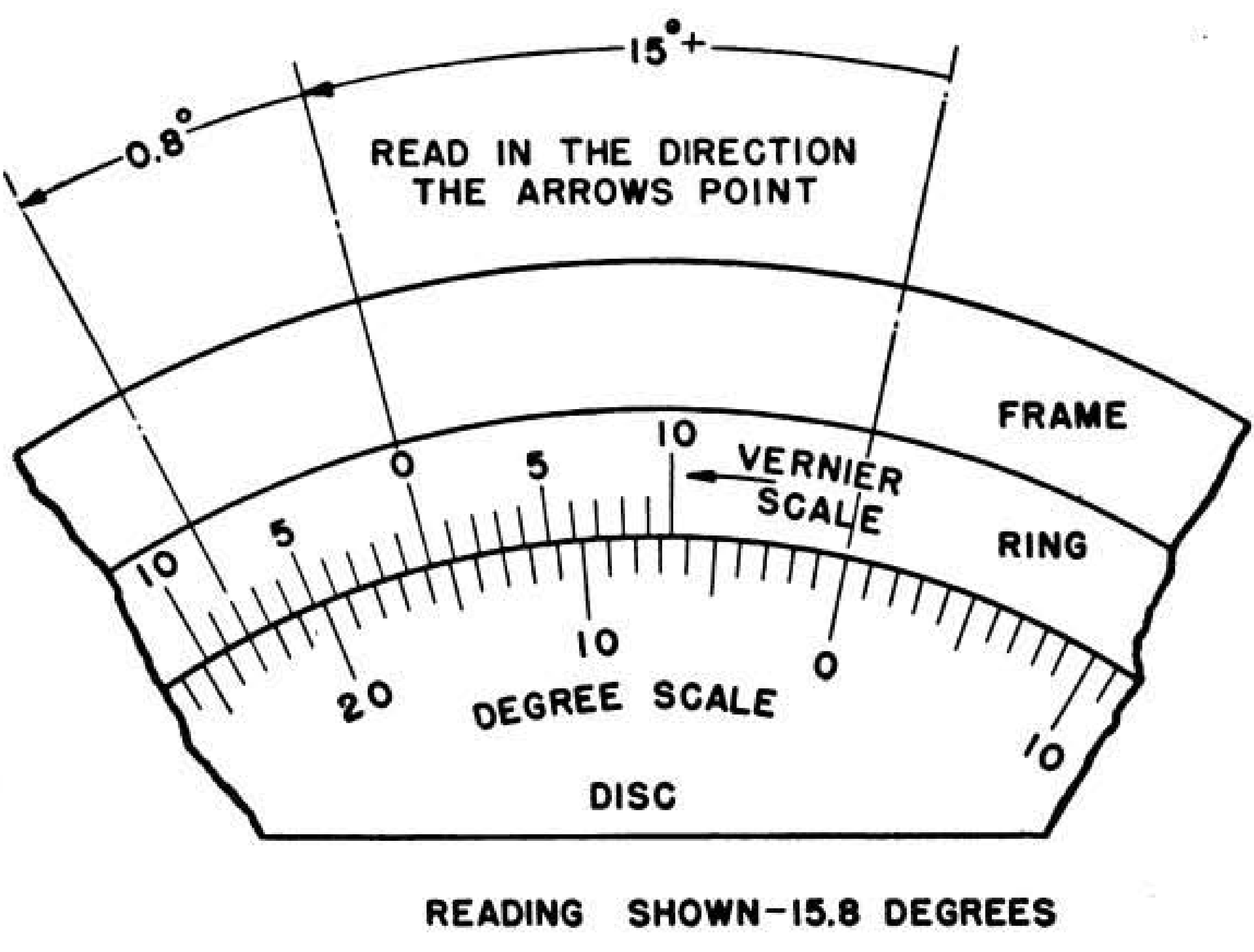


FIGURE 109.—Reading the universal propeller protractor.

c. The graduations of the whole-degree scale on the disk are degrees, whereas those of the vernier scale represent tenths of a degree. The number of whole degrees in the blade angle is determined by the number of degree-scale graduations between the zero of the degree scale and the zero of the vernier scale (fig. 109).

Ten points of the vernier scale are equal to nine points of the degree scale. The number of tenths of a degree in the blade angle is determined by the number of vernier-scale spaces between the zero of the vernier scale and vernier-scale graduation line that is nearest to perfect alignment with a degree-scale graduation line (fig. 109). The reading for tenths of degrees must always be made on the vernier scale in the same direction as the reading for degrees is made on the degree scale.

88. Measuring the blade angle.—*a.* Measurement of the blade angle is simply a determination of how much the flat side of the blade slants from the plane of rotation. Some airplanes rest on the ground in flying position so that the propeller shaft is in a horizontal position. The plane of propeller rotation, which is perpendicular to the axis of rotation or propeller shaft, is then a vertical plane. In this case, the blade angle is the number of degrees that the flat side of the blade slants from the vertical (fig. 110①). However, other airplanes rest on the ground in such a position that the propeller shaft is at an angle to the horizontal. The plane of propeller rotation, perpendicular to the axis of rotation is then at the same angle to the vertical as the propeller shaft is to the horizontal (fig. 110②, angle *A*). The number of degrees that the flat side of the blade slants from the vertical is in this case the blade angle *less* the ground angle of the airplane (angle *B* in fig. 110②). Therefore, to determine the actual blade angle, it is necessary to add the ground angle of the airplane (which is also the angle at which the plane of rotation slants from the vertical) to the angle at which the flat side of the blade slants from the vertical in the opposite direction (fig. 110②, angle *C*). By using the universal propeller protractor, these two angles, angle *A* and angle *B* in figure 110②, may be determined and added in two related operations, and the total angle, or blade angle *C*, may then be read from the degree and vernier scales of the instrument.

b. Following are the steps for checking and setting blade angles when the propeller is installed on the propeller shaft:

(1) With a lead pencil, mark the face of each blade to be checked at the blade station specified in Technical Orders for the particular propeller.

(2) Turn the propeller until the first blade to be checked is in a horizontal position with the leading edge up.

(3) Procure the universal propeller protractor, and swing the corner spirit level out as far as it will go from the face of the protractor.

(4) By turning the disk adjuster, align the zeros of both scales

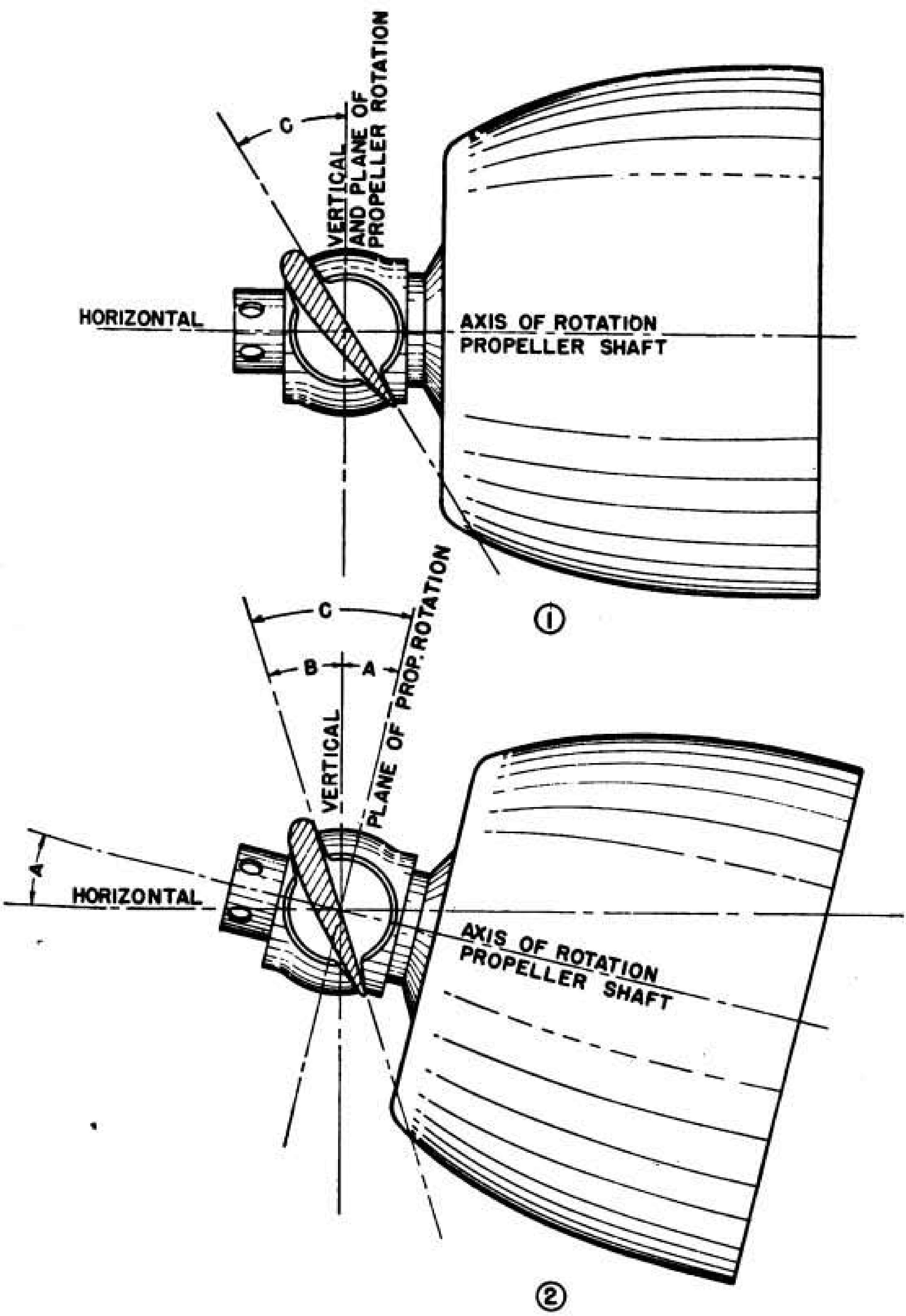


FIGURE 110.—Effect of airplane ground angle on measurement of blade angle.

and lock the disk to the ring by placing the spring-loaded pin of the disk-to-ring lock in the deep slot.

(5) Check to see that the ring-to-frame lock is released, and by turning the ring adjuster turn both zeros to the top (the curved edge) as shown in figure 108.

(6) Hold the protractor (by the handle, with the curved edge up) in the left hand. Place one vertical edge of the protractor across the outer end of the propeller retaining nut, or any suitable hub flat surface that is parallel to the plane of propeller rotation (at right angles to the propeller shaft center line). Then, keeping the protractor vertical by means of the corner spirit level, turn the ring adjuster until the center spirit level is horizontal. This sets the zeros of both scales at a point representing the plane of propeller rotation (see fig. 111, First operation).

(7) Lock the ring to the frame to fix the vernier zero so that it continues to represent the plane of propeller rotation.

(8) Release the disk-to-ring lock by pulling the spring-loaded pin outward and turning it 90°.

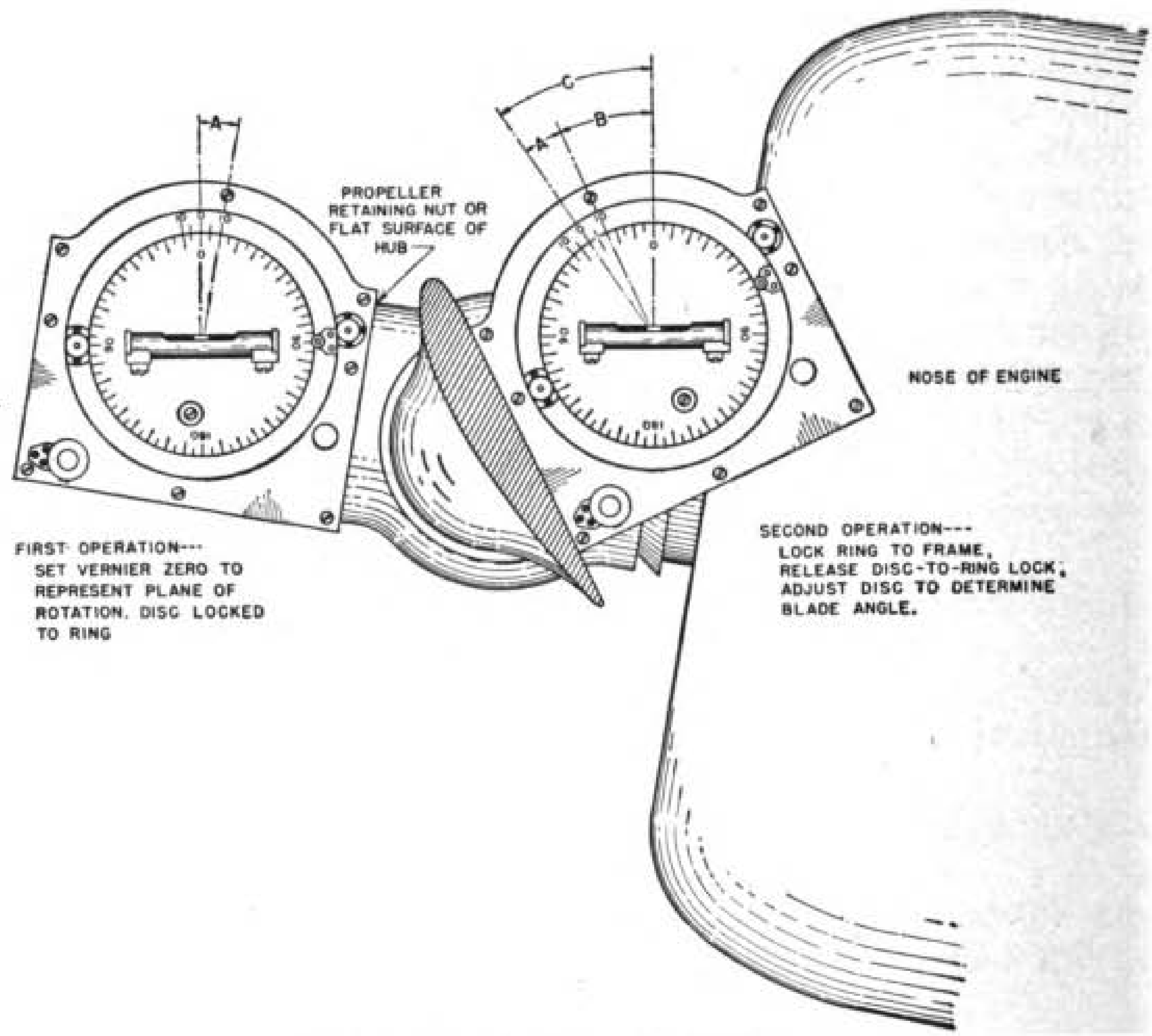


FIGURE 111.—Measurement of blade angle.

(9) Next, change the protractor to the right hand, holding it in the same manner, and place the other vertical edge (the edge opposite the one first used) against the blade at the mark which has been made on the face of the blade. Keep the protractor vertical by means of the corner spirit level, and turn the disk adjuster until the center spirit level is horizontal (see fig. 111, Second operation). The angle at which the flat side of the blade slants from the vertical is thus added to the angle at which the plane of rotation slants from the vertical in the opposite direction.

(10) The blade angle may now be determined by reading the number of whole degrees on the degree scale between the zero of the degree scale and the zero of the vernier scale, and the tenths of a degree on the vernier scale from the vernier zero to the vernier-scale graduation that most nearly lines up with a degree scale graduation.

(11) If necessary, make the required adjustments of the blade or the propeller pitch-changing mechanism to procure the specified blade angle.

(12) Repeat these operations for each of the remaining blades to be checked.

SECTION XIII

PROPELLER ANTI-ICING EQUIPMENT

89. General.—*a. Purpose of equipment.*—The operation of the propeller is seriously impaired by the formation of ice on the propeller blades and hub, not only because of the added weight, but also because of the alteration in the shape of the blade airfoil. The aerodynamic efficiency of the blades is materially lessened, and therefore the forward thrust produced by the propeller is decreased. For these reasons, means must be provided to retard the formation of ice on the blades and to eliminate any ice that may form. A rubber covered spinner may be provided to prevent ice from forming on the propeller hub.

b. Propeller anti-icing equipment.—Ice formation on propeller blades is prevented by a propeller anti-icing system which consists

of a supply of anti-icing fluid, a pump for metering out the fluid, a slinger ring for distributing the fluid to the blades, and a rubber feed shoe on the leading edge of each blade. Centrifugal force on ice particles on the uncoated surface of rotating blades is not sufficient to prevent the ice from building up. The continuous flow of anti-icing fluid over the blades, however, partially melts the ice and also serves to reduce its adhesiveness. Centrifugal force can then eliminate the ice particles from the rotating blades.

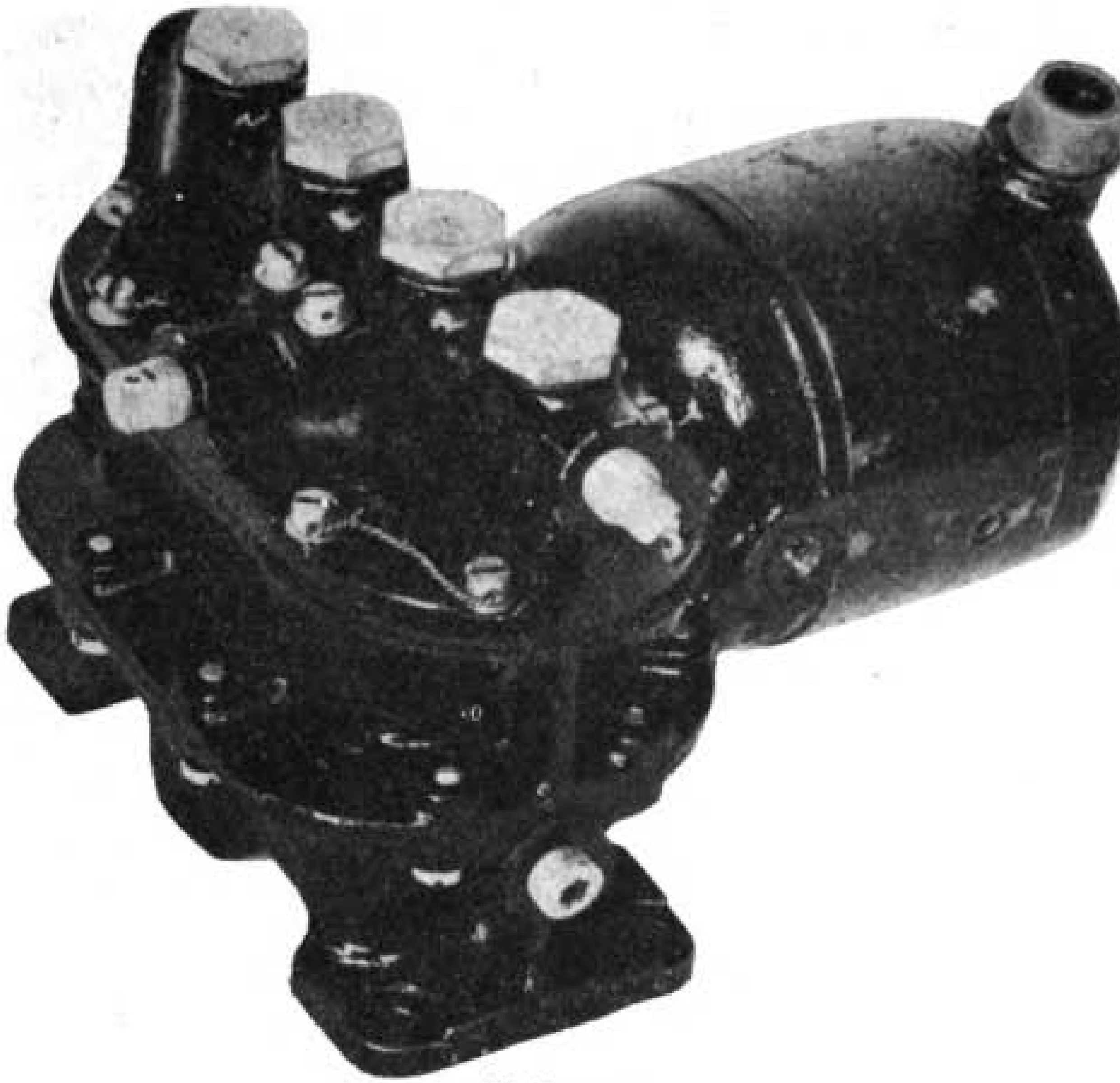
c. Rubber-covered spinner.—The propeller hub and the propeller pitch-changing mechanism are protected from ice formation by a rubber-covered spinner which is attached to the propeller hub. The rubber cover of the spinner is coated before each flight with a special deicer oil, which so effectively reduces adhesion of ice that the centrifugal force is sufficient to fling off any ice particles as they form.

90. Anti-icing system.—*a. Anti-icing fluids.*—Two types of anti-icing fluid are used. One type is a mixture of 85 per cent ethyl (grain) alcohol and 15 per cent glycerine. This fluid is used in installations which provide for propeller anti-icing only. The other type is 99 per cent isopropyl alcohol. It is used in installations having a single supply tank for propeller, windshield, and carburetor deicing systems.

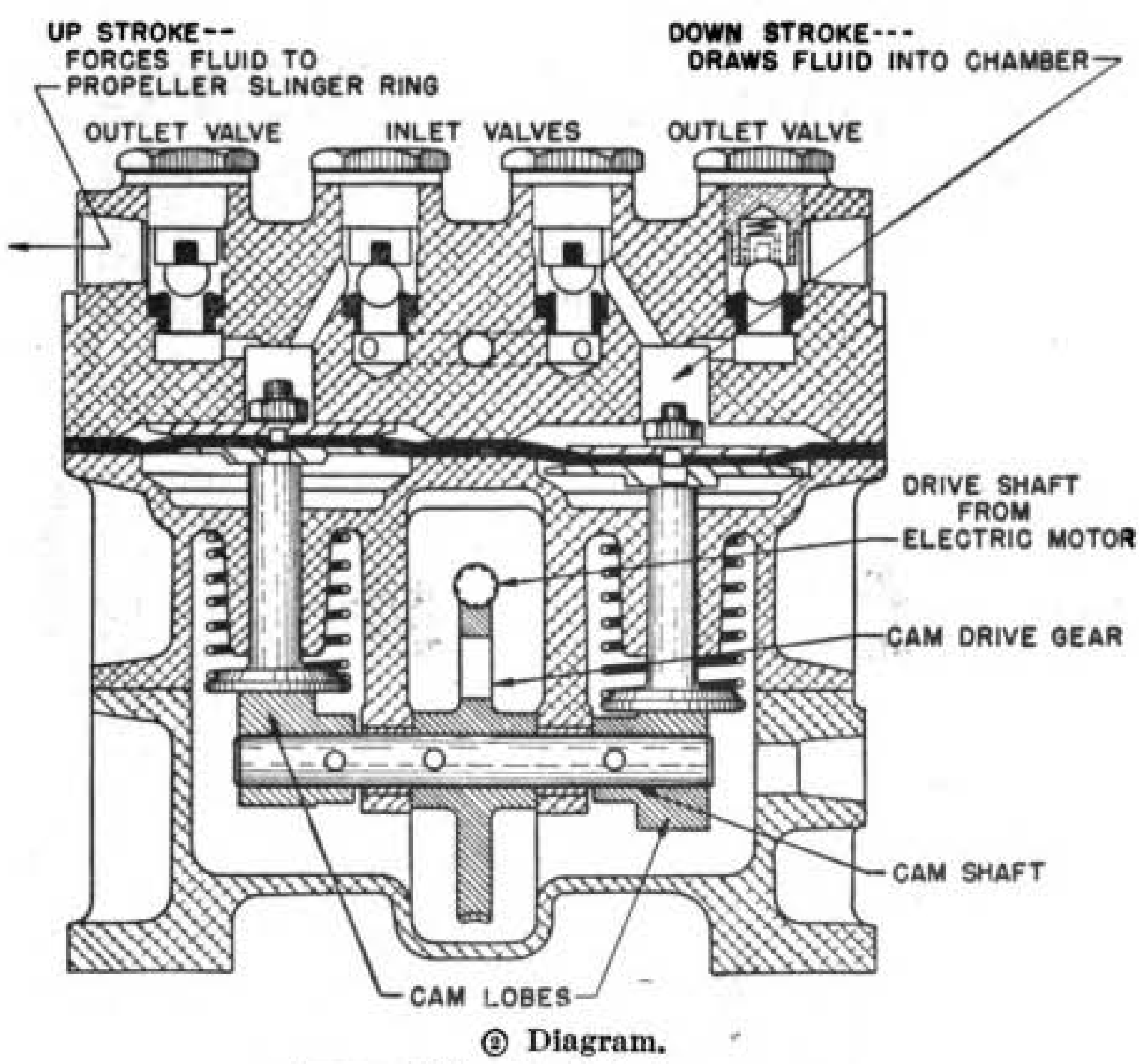
b. Pumps.—Several types of fluid-metering pumps for metering anti-icing fluid to the propeller blades are used in propeller anti-icing systems. These pumps are driven by electric motors and may be of the diaphragm, gear, or rotor type.

(1) *Diaphragm anti-icer pump.*—The dual-diaphragm pump (fig. 112①) is designed to supply a sufficient flow of fluid for two propellers. It has two fabric diaphragms which are actuated by a double cam driven by an electric motor through a worm reduction. This motor is designed to operate on 12 volts direct current. Steel-ball check values are used in the inlet and outlet passages of the pump (fig. 112②). An oil reservoir in the pump base provides a self-contained automatic method of lubrication. Oil is distributed to all moving parts, with the exception of the motor bearings, by means of the under side of the pump diaphragms which are connected with the oil reservoir.

(2) *Gear type pumps.*—One gear type anti-icer pump is a combination of two small gear type pumps contained in a bronze housing. The purpose of the two sets of gears is to provide independent discharge from two different outlet ports for a twin-engine installation. Two different pumps of this type are manufactured; one operates on 12 volts, and the other operates on 24 volts, both direct



① Pump.



② Diagram.

FIGURE 112.—Dual-diaphragm pump.

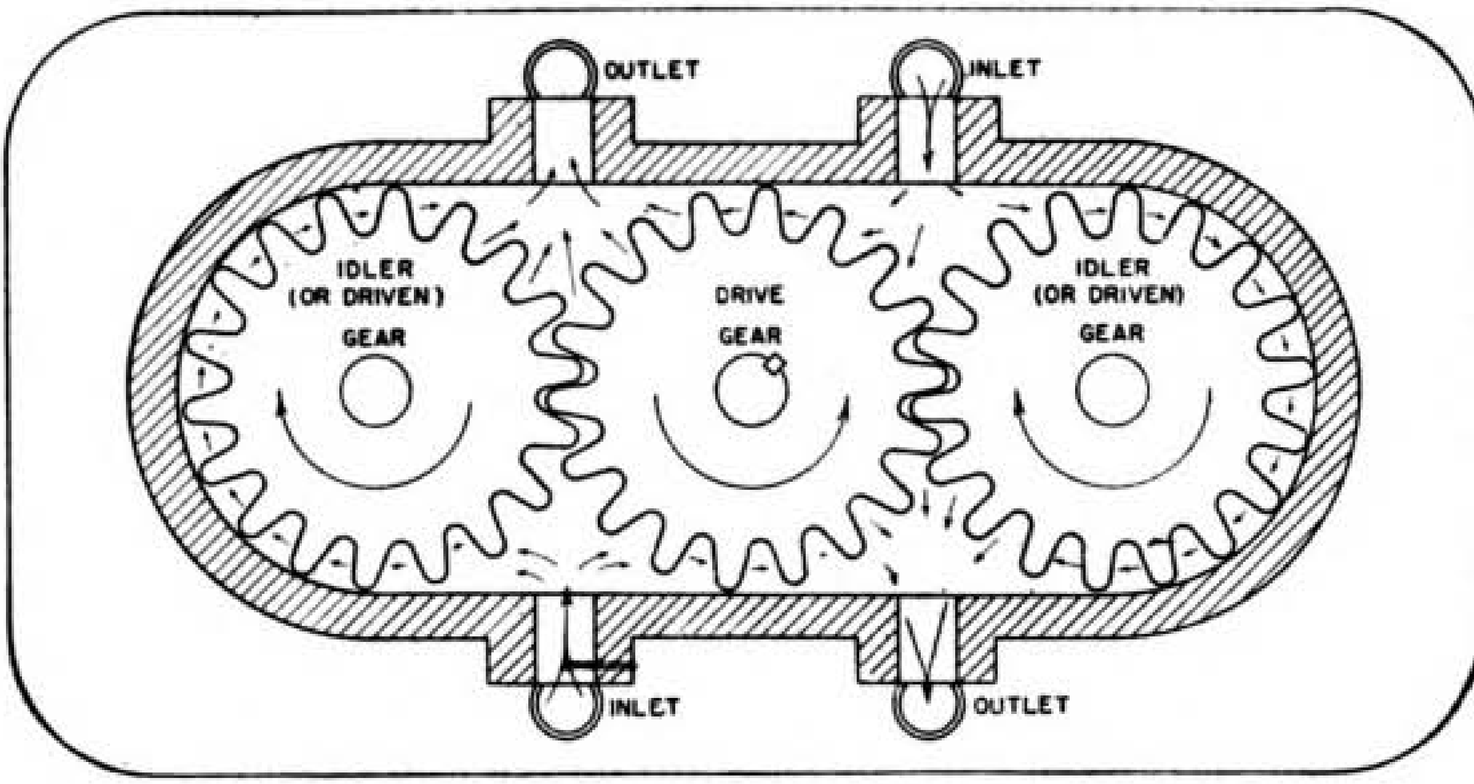


FIGURE 113.—Three-gear-type anti-icing pump.

current. Another gear type anti-icer pump is a three-gear pump that has one drive and two idler gears, all three contained in a bronze housing (fig. 113). The purpose of the two idler gears is to provide equal flow through two separate discharge ports independently of each other. This provides for a twin-engine installation. The pump motor is designed to operate on 24 volts direct current.

FIGURE 114.—Anti-icer control rheostat.

(3) *Rotor type pump.*—Two models of the rotor type pump are manufactured. In one of these, the dual-outlet unit, a single inlet serves a dual pumping chamber which provides uniform metering of the fluid between the two outlet ports. This unit thus lends itself readily to twin-engine installation. The single-outlet pump is adapted for use in single- or multi-engine installations (one pump per engine).

c. Control rheostat.—(1) *Description.*—A control rheostat (fig. 114) suitable for mounting on the instrument panel is provided with each pump. The unit consists of a wire-wound resistance coil, assembled in a cast alloy housing. A control knob moves a contact point along the coil, so that the resistance may be varied by including more or less of the coil in the electrical circuit to the pump motor. The amount of current allowed to flow to the motor controls the speed of the motor and the pump, and the speed of the pump determines the rate of output of anti-icer fluid. A plate is mounted on the face of the resistance-coil housing. It is marked to indicate the proper direction in which to rotate the knob to increase or decrease the output of the pump.

(2) *Operation.*—When the airplane encounters icing conditions in flight, the control rheostat is turned from OFF to the maximum-output position. The pump is allowed to deliver its maximum output of anti-icing fluid to the propellor blades for ½ to 2 minutes, depending upon conditions and the type of pump used. In any case, the rheostat should be left in the maximum-output position until the anti-icing-fluid lines are filled and the surfaces of all the propeller blades are covered with a small quantity of the fluid. The rheostat is then set so that the pump will deliver anti-icing fluid at a rate just sufficient to prevent ice formation on the blades.

91. Rubber-covered spinner.—The spinner is attached to the propeller hub. A resilient covering of rubber is cemented to the outside of the spinner (fig. 115). As the spinner rotates with the propeller, it is manufactured as a balanced unit, and when possible after its installation, the propeller is rechecked for balance. A special deicer oil or castor oil, applied to the rubber cover of the spinner, so reduces the adhesive properties of the rubber that the centrifugal force of rotation can cast off any ice that forms on it.

92. Installation.—The positions of the various units and the procedures for installation of a propeller anti-icing system depend upon the type of pump and the airplane involved. The standard installation drawings and the Technical Orders pertaining to the airplane in which the pump is to be installed should be consulted in each case. The instructions that follow are intended only as a

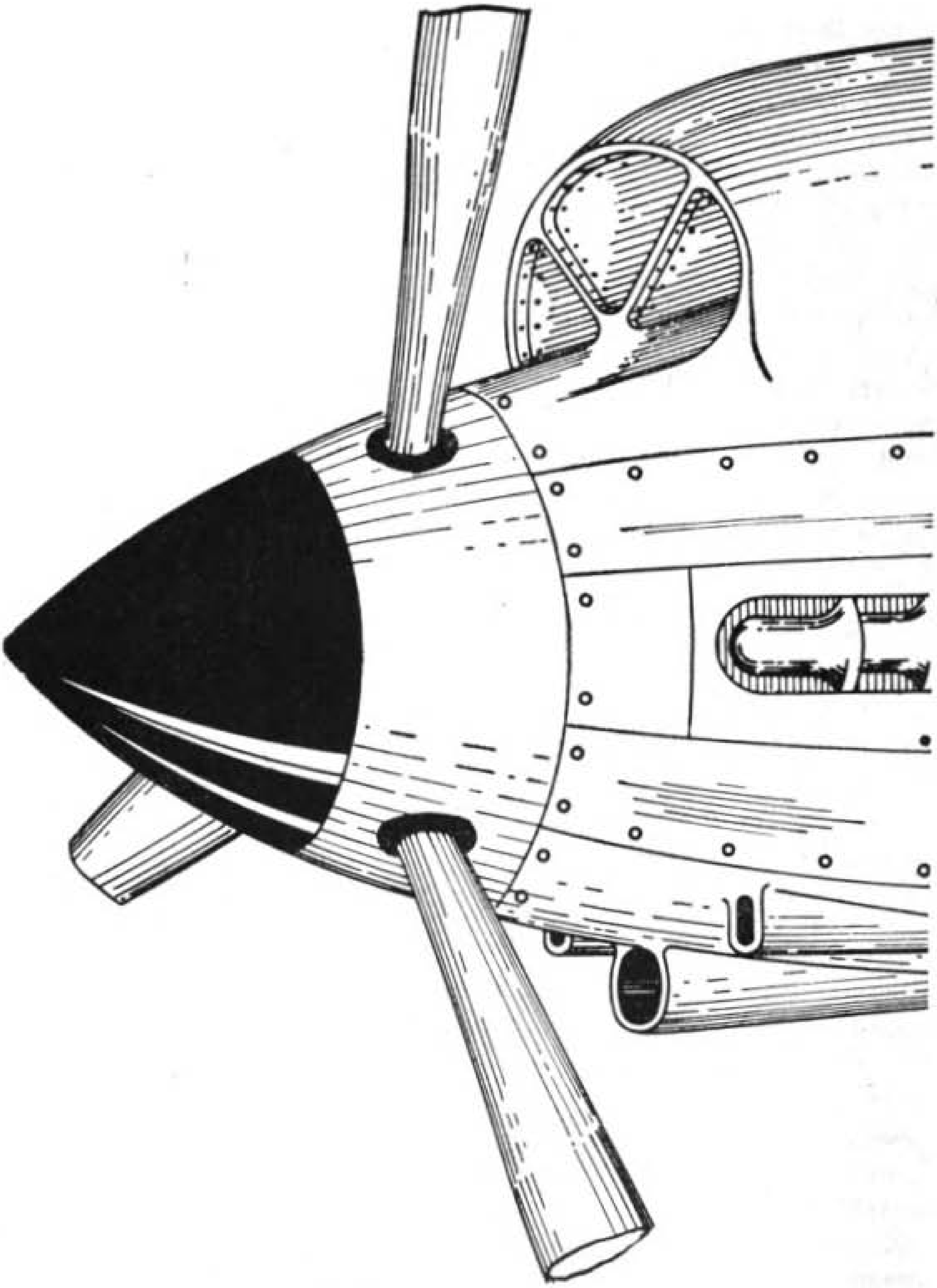


FIGURE 115.—Rubber-covered propeller spinner.

general guide and do not pertain to installation of propeller anti-icing systems in particular airplanes.

a. Supply tanks.—Supply tanks vary in capacity from one gallon on smaller airplanes to 20 gallons on heavy bombers that travel long distances at altitudes where icing conditions usually prevail. These supply tanks are usually located near the cockpit or cabin, and in some installations they may be replenished from containers while the airplane is in flight.

b. Slinger ring.—The slinger ring is merely a channel collector ring with a delivery tube for each blade. The slinger ring is either fastened to the hub by studs or is in an integral part of the hub. In either case, it rotates with the propeller assembly. Anti-icing fluid supplied by the pump drips into the slinger ring, and centrifugal force causes the fluid to flow through the delivery tubes and on to the rubber feed shoes which are attached to the leading edges of the blades. These shoes give a more even flow distribution of the anti-icing fluid.

c. Pumps.—For efficient operation, the several types of pumps must be mounted in different positions in relation to the supply tank and the slinger ring. This is because of differences in construction and in principles of operation.

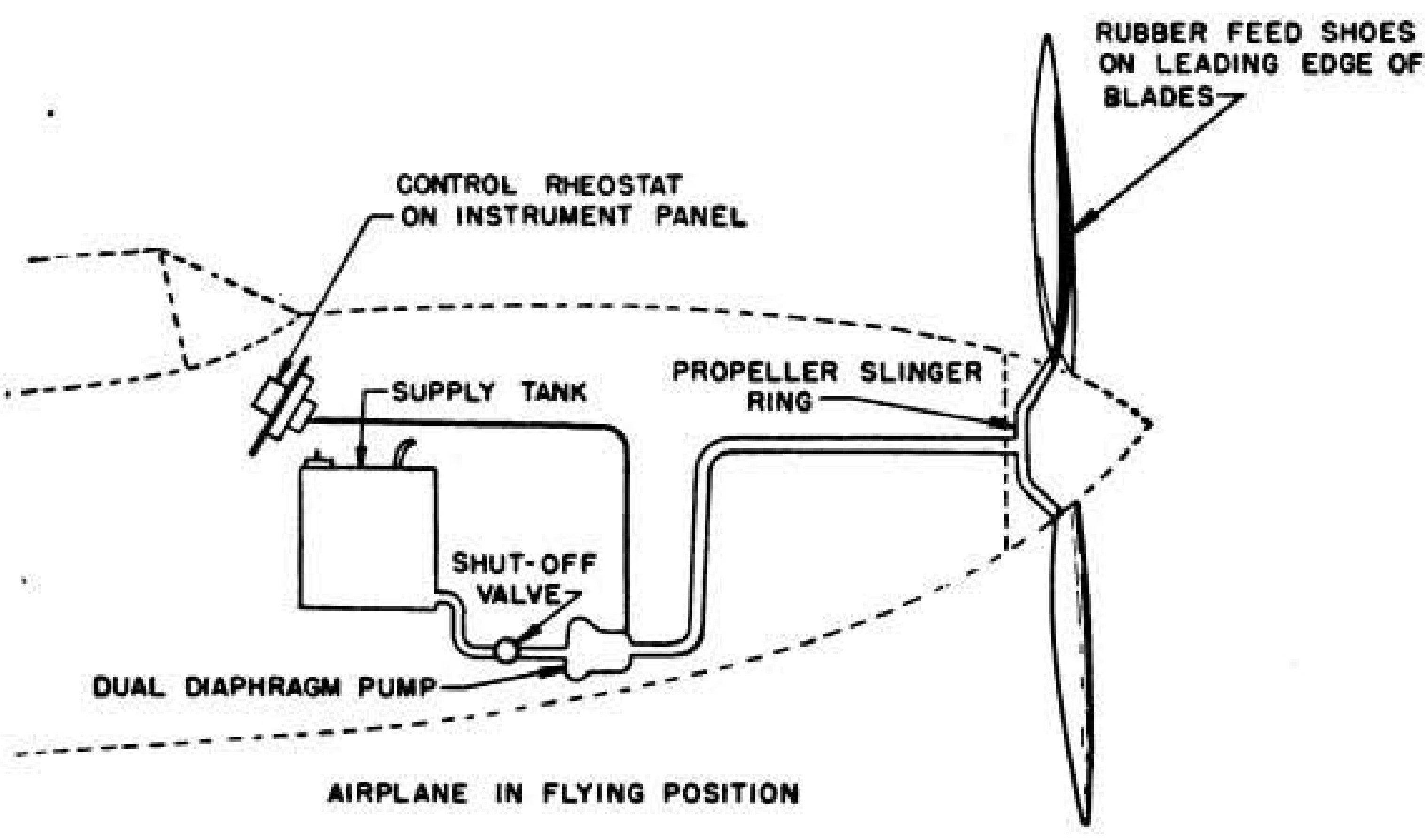


FIGURE 116.—Typical anti-icing system using a dual-diaphragm type pump.

(1) *Dual-diaphragm pump.*—In the installation of propeller anti-icing systems using the dual-diaphragm pump, the supply tank should be located approximately 6 inches above the pump. This is necessary to provide gravity feed for the pump. The supply

tank should also be located level with, or below, the propeller outlet and when the airplane is in flying position. This is necessary to prevent the anti-icing fluid from draining out when it is not needed (fig. 116). Antidrain check valves may also be installed in the line for this purpose. The dual-diaphragm pump should be mounted in a horizontal position in any convenient location where it is readily accessible for inspection and priming. This pump should be primed when it is first installed and whenever the supply tank runs dry. To prime it with the electric motor running, back off the two inlet valve plugs approximately three turns. Allow the pump to run until all air is expelled from the system and a steady flow of liquid is obtained; then tighten the valve plugs. A shut-off valve should be installed in the line between the supply tank and the pump to permit the removal of the pump for servicing without the need of draining the supply tank.

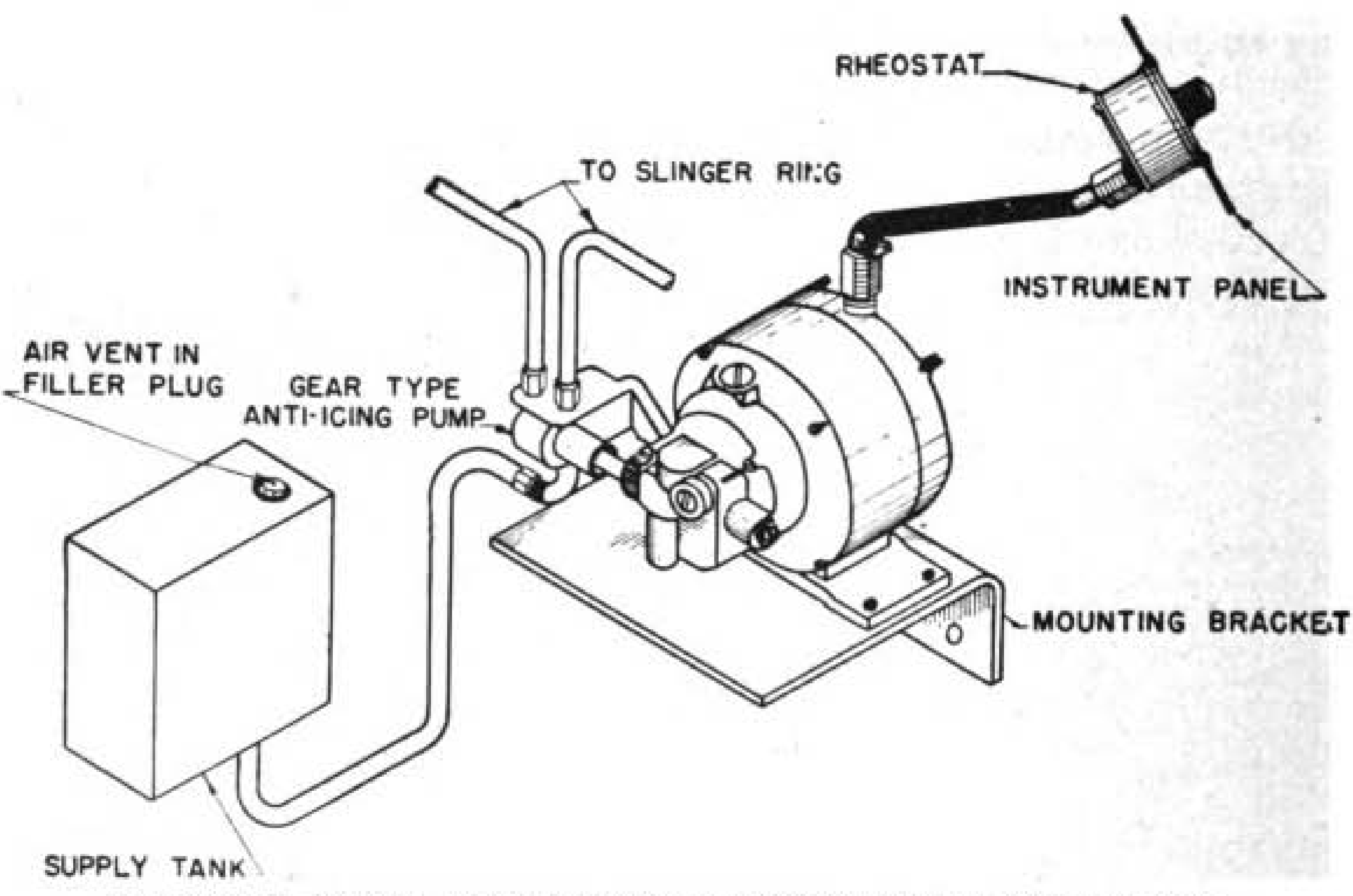


FIGURE 117.—Typical anti-icing-system installation using a gear type pump.

(2) *Gear type pumps.*—If the supply tank is located above the propeller outlet end, the gear type anti-icing pump must be located so that the center line of the pump is slightly above the top of the supply tank, but not more than 24 inches above the intake-line connection at the supply tank, with the airplane in flying position. If the pump center line is below the top of the supply tank, the hydraulic head, or pressure of the fluid due to the force of gravity, may force part of the fluid through the pump when it is not needed.

On the other hand, in order to insure sufficient dry lift, the intake line should not extend more than 24 inches below the pump (fig. 117). If the supply tank is located well below the propeller-outlet end, the pump may be located below the supply tank. A shut-off valve is installed between the supply tank and the pump in this type of installation.

(3) *Rotor type pump.*—The rotor type pump may be mounted above or below the supply tank. If the tank is located above the propeller-outlet end, a lightly loaded check valve, just sufficient to check the hydraulic head of the fluid, should be installed to prevent accidental drainage from the tank. If the tank is located below the level of the propeller-outlet end of the system, a check valve is not required, but care should be taken not to exceed the dry-lift limits of the pump.

d. Control rheostat.—The control rheostat should be installed on the instrument panel by means of the mounting holes provided. Reference should be made to the wiring diagrams of the particular airplane for electrical connections.

e. Tubing.—The tubing required for the propeller anti-icing systems should be of the type specified in Technical Orders.

93. Inspection and maintenance.—*a. Anti-icing system.*—(1) Before each flight during which icing may occur, the supply tank should be checked to insure a sufficient supply of anti-icing fluid for proper operation of the system. At the periodic inspections specified in Technical Orders, the entire anti-icing system should be checked for security of mounting and for leaks in any of the connections. All electrical connections in the system should be inspected for tightness. The pump motor brushes, spring assemblies, and commutator should be inspected for cleanliness and proper operation. Brushes worn to the minimum length specified in Technical Orders for each type of pump will be replaced.

(2) If the anti-icing system is not operated regularly, the fluid in the tanks may become congealed, and corrosion may occur in the pumps. Congealing is caused by evaporation of the alcohol when the fluid is not kept thoroughly mixed. The glycerin is left as a jellylike deposit on the bottom of the tank. For this reason, the system should be operated at least once a day during service in order to keep the fluid properly mixed. If conditions are such that this is not possible or practicable, the tank should be drained and the specified cleaning solvent pumped through the system to prevent corrosion of the affected parts.

(3) After each flight in which the propeller anti-icing system has been operated, the propeller blades and hub, and the slinger

ring will be washed down and all traces of fluid removed. The propeller blades and hub will be coated with clean engine oil.

b. Rubber-covered spinner.—(1) Prior to the first flight of each day, the rubber cover of the spinner is coated with a special deicer oil or castor oil. Before this oil is applied, the rubber cover should be cleaned with a cloth moistened with denatured alcohol.

(2) On the completion of each day's flying, the rubber cover of the spinner is thoroughly coated with another special oil. This second oil is a preservative and retards the checking (cracking) of the rubber. Rubber-covered spinners are removed from airplanes during the summer months when icing conditions are not likely to be encountered, and are put in storage. While in storage, the rubber cover of each spinner is coated with the special preservative oil at least once every 3 months. This practice prevents unnecessary deterioration of the rubber.

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